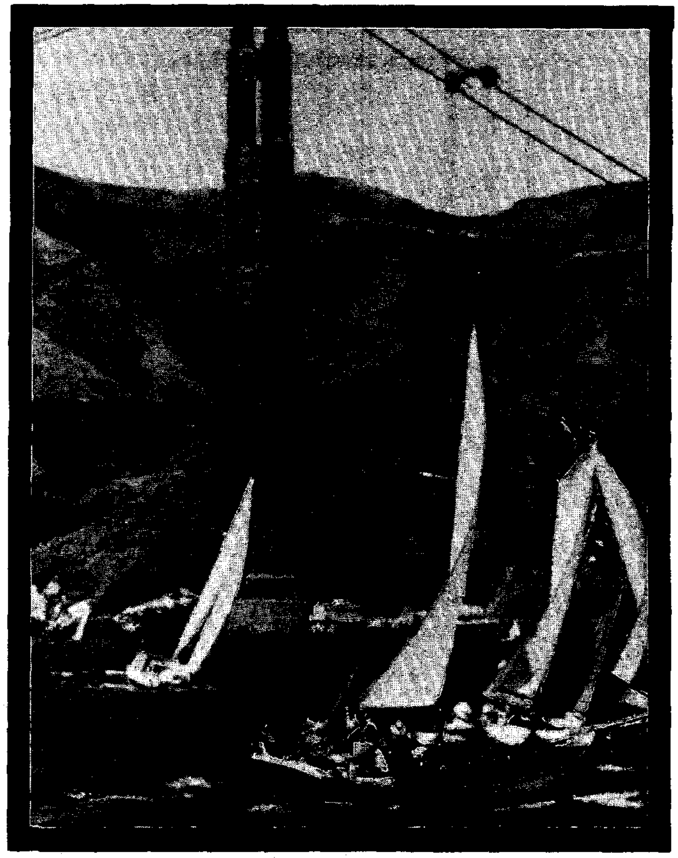
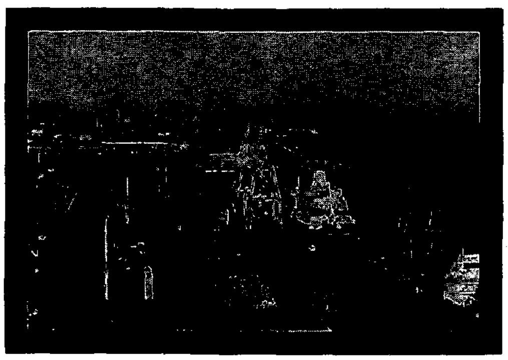
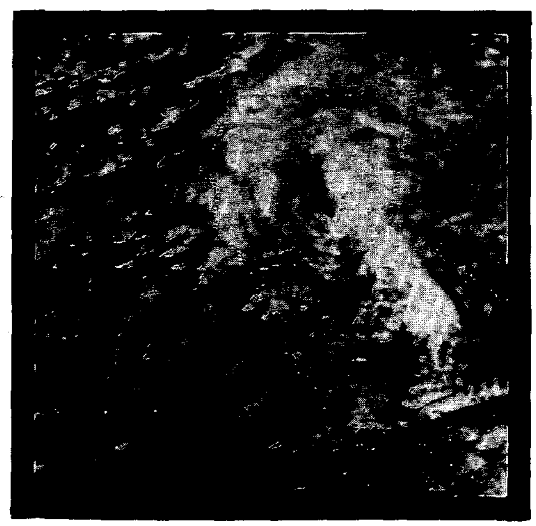
Marine Environmental Assessment

SAN FRANCISCO BAY
1985 ANNUAL SUMMARY







U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Environmental Satellite, Data, and Information Service
Assessment and Information Services Center

E IMPACT ASSESSMENT
STATES

Marine Environmental Assessment

SAN FRANCISCO BAY
1985 ANNUAL SUMMARY

Michael J. Dowgiallo
Isobel C. Sheifer
Fred G. Everdale
Martin C. Predoehl
Karl B. Pechmann
Sylvia Z. Green
Kurt W. Hess
Richard P. Stumpf

Marine Assessment Branch
Marine Environmental Assessment Division

Washington, D.C.
AUGUST 1986

U.S. DEPARTMENT OF COMMERCE
Malcolm Baldrige, Secretary

National Oceanic and Atmospheric Administration
Anthony J. Calio, Administrator

National Environmental Satellite, Data, and Information Service
Thomas N. Pyke, Jr., Assistant Administrator

Assessment and Information Services Center
Joan C. Hock, Director

TABLE OF CONTENTS

CONTENTS (Continued)

LIST OF FIGURES

LIST OF FIGURES (Continued)

LIST OF TABLES

LIST OF TABLES (Continued)

1. INTRODUCTION

This San Francisco Bay assessment is a prototype summary covering the calendar year 1985 which includes information on weather, oceanography, fisheries, recreation, transportation, and pollution. The Assessment and Information Services Center has produced assessments for other areas along U.S. coasts including Chesapeake Bay, Gulf of Mexico, and Puget Sound.

The assessment focuses on the effects of environmental events (weather, oceanography) on economic sectors of marine environmental activity and provides a multidisciplinary view of San Francisco Bay highlighting its multiple uses. Relationships between study variables are presented where possible. Where it is difficult to establish clear relationships, data from scientific and economic areas are presented to further display the multiple use of the bay-delta system.

1.1 Organization of the Report

The report is comprised of nine sections. In the introductory section we delineate the concept of marine environmental assessment embodied in this report, specify the coverage of the present study, and describe the marine-oriented economy of the San Francisco Bay area.

Section 2 provides an overview of the highlights of the environmental events identified in 1985 in the study area and the impacts of the events on sectors of the local economy.

Sections 3 and 4 describe the weather and oceanographic conditions which prevailed during 1985. Study variables are presented with the observed 1985 values and long-term averages (when possible) to show how the 1985 weather and oceanography compared to a "normal" year in the study area.

Fisheries, Recreation, and Transportation are addressed as sectors of the marine-oriented economy in Sections 5 through 7. The Fisheries section focuses on the fish and shellfish which were landed in bay ports and on species which use the bay for portions of their life cycles. In Recreation, we provide an overview of marine-related recreation in the San Francisco Bay area by identifying the categories of recreation and describing their importance to the regional Bay economy. The Transportation section presents information on shipping and related shore activity for the major ports of San Francisco Bay during 1985. Pollution, which is a topic of major concern in the region, is addressed in Section 8, and includes information on pollutant sources, spills, and effluents.

The last section of the report is a summary of research activities which were conducted by local organizations around the Bay during 1985.

1.2 Description of the Study Area and Scope of the Report

The study area includes San Francisco Bay and the San Joaquin-Sacramento River Delta and drainage basin, and the adjacent coastal ocean (Figure 1.1). Meteorological station data extend throughout the drainage basin of the

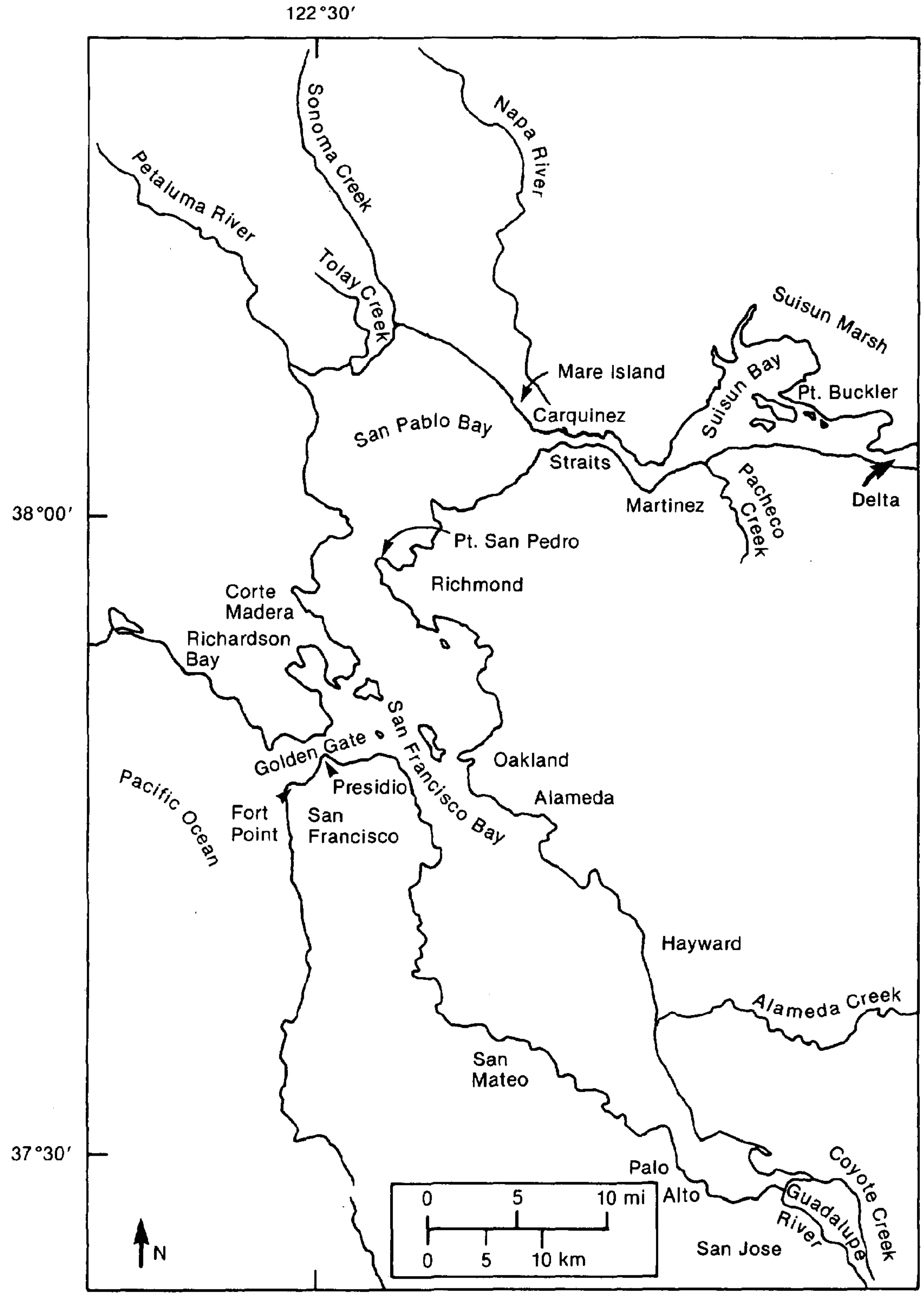


Figure 1.1 Map of the San Francisco Bay area, depicting marine features (modified U.S. Fish and Wildlife Service map).

bay-delta system. The study area for the adjacent coastal ocean extends north to Canada and south to the Baja peninsula for the analysis of sea surface temperatures and wind-induced mass transports.

The study period covers the calendar year 1985. If discussion of environmental patterns or events requires reference to 1984 or 1986, coverage is extended at those specific instances.

The San Francisco Bay-Delta system is the most important hydrologic unit in California, and is used intensively for both recreational and commercial purposes. A primary aim of this assessment is to address the uses of the bay that are important to the area economy. For example, the bay serves as a nursery area for fish species that use the bay for a portion of their life cycles. It also provides a limited commercial fishery and a sport fishery. Large quantities of fish and shellfish are caught outside the Golden Gate and are landed in bay ports. The bay provides wildlife habitat, and therefore, land use and water quality are important for the survival of many species. Recreational uses of the bay such as boating, sightseeing, birdwatching, and sail-boarding are included in the assessment as they are important to the area economy and they provide aesthetic enjoyment. Commercial shipping and water usage for industry and agriculture underscore the importance of the bay as a resource.

1.3 The Marine-Oriented Economy of the San Francisco Bay Area

While the economy of the San Francisco Bay area is no longer dominated by water-borne commerce and waterfront industry as it was in earlier years, the bay delta itself has an enormous impact on the regional economy. Scenic and recreational qualities of the Bay and its waterfront generate a pattern of usage and development, including tourism, whose direct and indirect values enrich the economy as well as the quality of life in the region. It is significant that the nine counties around the Bay are considered a single region, "the Bay Area" indicating the type of development that the Bay has fostered. This region has been one of the fastest-growing in the nation, although in 1985 the pace slowed somewhat. It is one of the most affluent areas in the country. The Association of Bay Area Governments (ABAG) projected the population for the nine-county Bay area as over 5.5 million in 1985. The three largest cities in the area were San Francisco (719,200), San Jose (696,000), and Oakland (351,100). ABAG estimates that the population will reach 5.8 million by 1990. Figure 1.2 shows the county divisions in the Bay Area and the 20 largest cities.

Like the citizens around many of the nation's estuaries, residents have made economic trade-offs to accommodate multiple uses of the bay. These trade-offs involve choices about future development. In 1965 the California State legislature passed the McAteer-Petris Act, a comprehensive and enforceable plan for the conservation and controlled development of the shoreline of San Francisco Bay. The Bay Conservation and Development Commission (BCDC) was established in the same year as a temporary agency. A Bay Plan was developed to carry out these goals. In 1969, BCDC was made permanent and the policies of the Bay Plan were largely incorporated into new legislation. Filling of the bay was restricted to only water-oriented uses and for improving shoreline

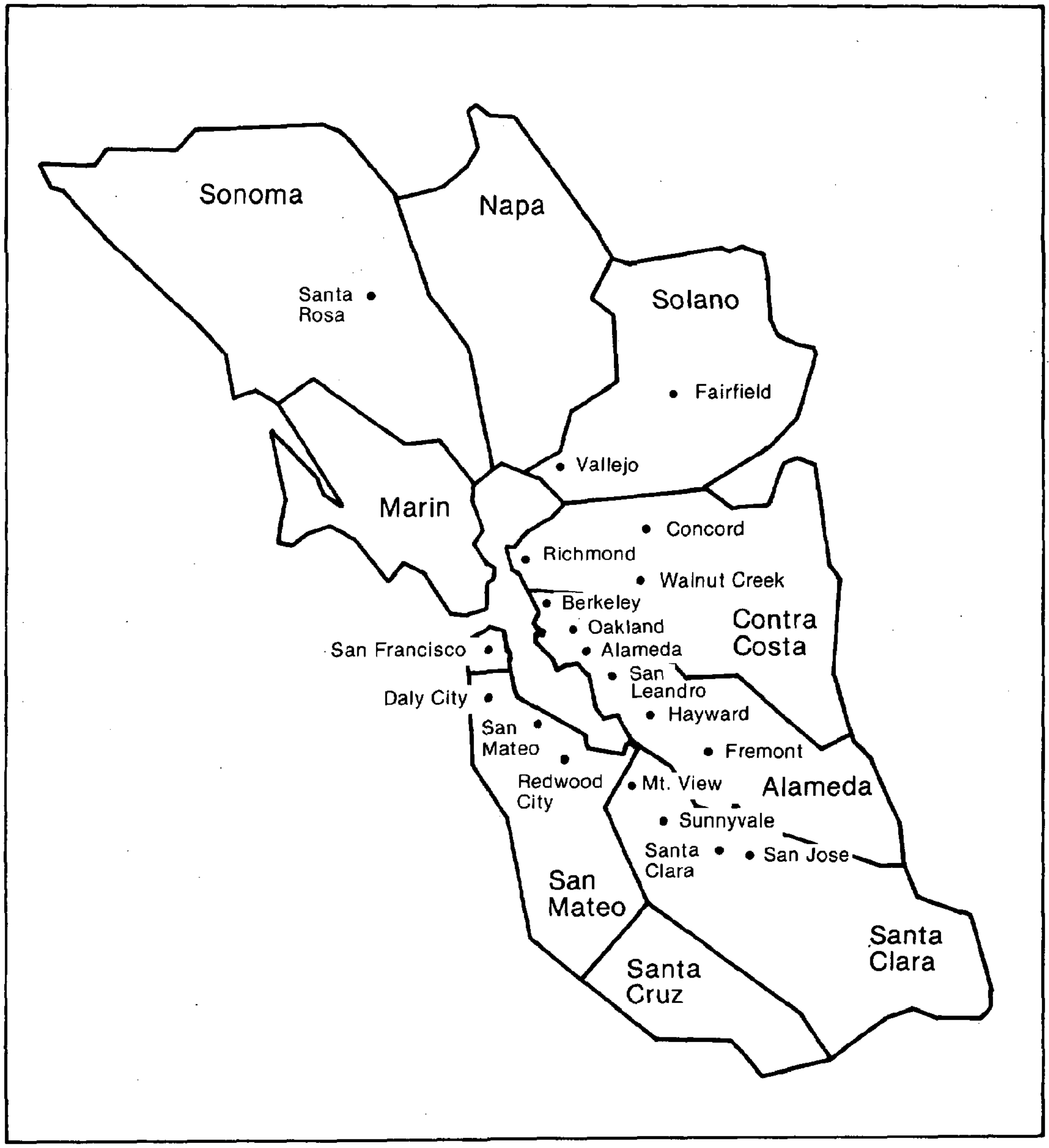


Figure 1.2 Map of San Francisco Bay region showing county divisions and 20 largest cities.

appearance and public access to the bay. Certain shoreline areas were also reserved for high priority uses. Other policies in the Bay Plan promote scenic, recreational, and water quality values of the bay. Although BCDC has sometimes made controversial decisions, it has provided a mechanism for the pubic resolution over conflicts on the uses of the bay and its shoreline in accordance with these standards. The Commission has been a significant factor in reducing bay fill (in the past five years, the bay has actually increased in size by 70 acres per year), increasing enjoyment of bay shoreline, and aiding development. Its decisions, have in turn, affected the kind of economic development that will take place around the Bay.

Unlike the commercial development of earlier years, the modern San Francisco Bay area is dominated by finance, retail trade, services, and manufacturing (a significant share of which is high-tech). In 1985 ABAG projected employment in the 9-county area as 2,780,500 people. By far the largest number of jobs was in services with 791,100. Manufacturing jobs totaled 551,000 and retail trade had 451,300 people. Figure 1.3 shows the projected 1985 and 1990 job distribution in the area. It indicates that these three job categories are likely to continue to grow. Symbolizing the high technology-orientation of manufacturing is the Silicon Valley, an area noted for the production of computers and computer products. This region begins south of San Francisco, stretches from San Mateo County through Santa Clara County. The type of employment in the San Francisco Bay area generates high incomes. As a result, per capita income in all 9 counties was above the national figure in 1980, and Marin County exceeded that figure by 69 percent. The Census Bureau has estimated that Bay area incomes will be the highest in the country by 2000.

The character of the employment and incomes in the region also affects attitudes toward the bay and its waterfront. High incomes and leisure time allow people to engage in recreational pursuits. The bay is a hub of this activity. San Franciscans like their bay and want to enjoy its waters and vistas. These same scenic and recreational values also attract tourists. California is the nation's leading travel destination. A survey by the State of California determined that 33 percent of the tourists were seeking outdoor recreation. San Francisco is a leading destination. Recreation and waterfront visits by both tourists and residents create tremendous economic activity (see section 6). Although it is hard to find specific dollar figures for some of these activities, the pursuit of recreation on or near the bay and actitivites around the bay that are enhanced by scenery quite obviously generate the spending of billions of dollars that multiply throughout the economy. In 1985 tourists who stayed in overnight facilities in San Francisco were estimated to have generated total expenditures of $1.3 billion (see section 6.6, Tourism).

The employment and income characteristics of the population must be taken into account when considering attempts to divert more water from the Sacramento-San Joaquin river system. Water diversion is a critical topic as residents see these diversions as causing problems for the bay-delta. It has been argued that these diversions cut down flushing action and thereby raise pollutant levels which detrimentally affect marine life. Residents outside the Bay Area feel they need this water for a variety of important activities including agricultural irrigation and drinking. In recent years, an attempt to build a canal to divert water to the Central Valley, mainly for crop irrigation, was defeated but not without a great deal of acrimony. Agriculture is significant

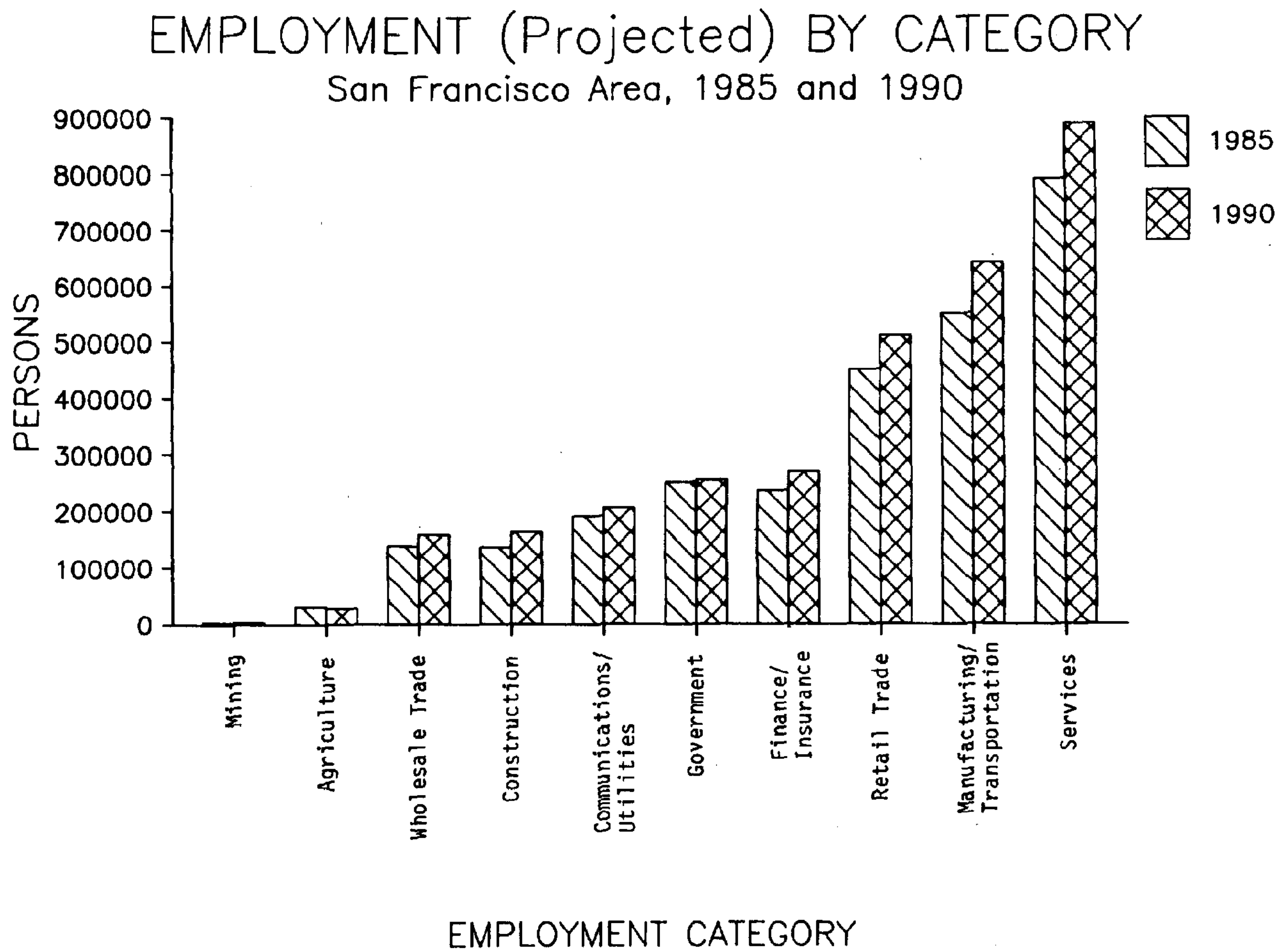


Figure 1.3 Employment in San Francisco Bay area (projected) by category, 1985 and 1990. Source: Association of Bay Area Governments.

to the California economy; it is approximately a $14 billion industry that employs about 3 percent of the working force. However, only 30,900 people are employed in agriculture in the Bay Area, i.e., about 1 percent of the region's workforce, and these people would not have largely benefited from the diversions. On the other hand, the value of a healthy bay to those who fish, boat, and otherwise enjoy the waters of the bay-delta has significant economic value. The sales generated by these recreational pursuits is quite significant, and many people, particularly in the service sector, draw employment from bay-related recreation.

Toxicants present another issue on which economic give-and-take concerning the quality of Bay waters takes place. Environmental groups seeking to preserve both clean water and the health of fish and wildlife have waged energetic and vocal campaigns to reduce the amount of pollutants (including heavy metal compounds, polychlorinated biphenyls, pesticides, and petroleum-based hydrocarbons). Progress in controlling outflows that contain these toxics has been significant. However, environmental groups argue that much more remains to be done. Improvement might require, among other things, higher standards, pretreatment of wastes, and greater government surveillance of discharges. All of these would mean greater costs both to industry and the public. How the issue is resolved will determine, in part, the kind of development that takes place around the bay.

The necessity for making decisions regarding the quantity and quality of water will continue to be important matters, particularly as the availability of fresh water to meet the needs of growing populations continues to diminish and the demands of agriculture increase. It is in this context that this environmental assessment of San Francisco Bay has a broader meaning. It gives us some insight into the problems other estuaries may face as the areas around them become increasingly developed. It also emphasizes the fact that environmental issues in estuaries are frequently resolved through the political process and that this process involves a complex series of economic and social choices which, in turn, shape future economic development.

Table 2.1 Environmental impact summary, San Francisco Bay, 1985.

	ECOSYSTEM				WATER/WATERFRONT			ECONOMY	
EVENT	Water quality	Phytoplankton Blooms (S. Bay)	Fish Abundance	Health of Marine Wildlife	Commercial Facilities usage	Recreational Facilities usage	Tourism/Travel	Business income	Jobs
Reduced freshwater inflow	-	-							
Dry weather		-			+	+	+	+	+
High winds, increased water mixing	+	-							
Return to normal water temp. following '82-'83 anomaly			+		+	+		+	+
Humpback whale strays into the Bay						+	+	+	+
Late Feb. temps. higher than normal						+	+	+	+
High levels of selenium are found in Kesterson Resevoir	-			-		-			
6 spills of oil/hazardous substances of 1,000 gallons or greater	-		-	-		-			
Falling gasoline prices						+	+		
$ value of water-borne exports & imports declines in San Fran. Customs Dist.					-			-	-
Unusual no. of heavy-fog days in Delta area in Jan. and Dec.					-			-	-

+ Favorable

- Unfavorable

(blank) No identifiable effect, data unavailable, or not applicable

2. HIGHLIGHTS - GENERAL EVENTS AND IMPACTS

Weather and climate

-1985 was an unusually dry year in the San Francisco area and much of Northern California. Winter months were characterized by both drier-than-normal and colder-than-normal conditions. There was a lack of storms which meant less accumulated snow pack in the mountains surrounding the Central Valley of the Sacramento and San Joaquin Rivers and consequently, insufficient soil moisture to sustain the high-intensity agriculture of the area.

-The continuation of below-normal rainfall through most of the summer, in addition to warmer-than-normal temperatures and greater-than-normal wind speeds exacerbated the dry conditions which began in the winter months.

Oceanography and hydrology

-Dry conditions affected streamflow, which was below normal, and salinities, which were above-normal.

-Stronger-than-normal spring winds favored more vigorous vertical mixing of shallow bay waters.

-The dry conditions in 1985 appear to have had an effect on phytoplankton blooms in the South Bay. A strong bloom did occur in the spring in South Bay, though a second expected bloom did not occur. Reduced river flow and less stratification may have contributed to the absence of the second bloom event in South Bay.

Fisheries

-Commercial fisheries in the San Francisco area showed an increase in total landings worth $20.9 million, in 1985 over 1984. Forty-three million pounds of finfish and shellfish were landed at ports in the San Francisco area in 1985, Pacific herring landings were 17.3 million pounds, double the 1984 landings. The increase in landings of herring marks a recovery for that species, following the period of anomalously warm sea surface temperatures in 1982-83. Herring and several other commercially important species moved from their traditional fishing grounds and showed reduced growth following the unusual warming. Water temperatures in 1984 and 1985 returned closer to normal, and herring, chinook salmon, and other species showed an increase in landings and a return to more normal seasonal growth.

-Water temperatures in 1985 were closer to normal than in the unusual warm period of 1982-83, though water temperatures have been above normal on the west coast for the past ten years. More subtle evidence of warmer-than-normal water temperatures was seen in the occurrence of warm water species which normally are not found in the colder areas of the west coast. In 1982-83, over 30 unusual species were noted. In 1984 and 1985, some of these species were still being reported, coinciding with the above-normal water temperatures.

Recreation

-1985 was an excellent year for recreational activities around the bay. Park attendance, number of charterboat anglers, recreational boating registrations, wildlife refuge visits, and tourism showed upturns from 1984.

-The unexpected visit of Humphrey, the humpback whale, in late October created a tourist and media event that favorably impacted motel/hotel occupancy, restaurant business, and souvenir sales.

Transportation

-The dollar value of both water-borne imports and exports through the San Francisco Customs District declined in 1985 from 1984 levels. Although most of the seven ports of the Bay Area showed the declines, the Port of San Francisco showed an upturn in both categories.

-An unusual number of days with heavy fog in Stockton and Sacramento in both January and December caused delays to shipping.

Pollution

-Reduced freshwater flow probably resulted in higher concentrations of pollutants in incoming waters, though total loading of the Bay was probably lower than normal.

-Total number of spills in the 12th Coast Guard District for 1985 were 594. There were 464 spills of oil, 63 spills of hazardous substances, and 67 spills of other materials. Six spills were of 1,000 gallons or greater in the San Francisco Bay.

-Results of a special one-year monitoring program instituted in May 1984 to study the types and concentrations of toxic pollutants discharged into San Francisco Bay from 32 publicly-owned treatment works (POTWs) showed that the San Francisco Bay area POTWs in general discharge minor amounts of toxic organic pollutants at concentrations well below existing Federal ambient water quality criteria for salt water and fresh water aquatic life. However, toxics from other sources and other types of pollutants remain a serious concern.

3. WEATHER

3.1 Introduction

The climate of the San Francisco Bay area and other coastal areas of California is generally mild in all seasons - governed by the position of the North Pacific high-pressure cell (Pacific High) and the moderating influence of the ocean. The ocean keeps the maximum to minimum temperature range small, both diurnally and seasonally . Cold, upwelling water keeps the summers cool; the on-shore flow from the relatively warm ocean water keeps the winters warm. The Pacific High builds northward in the spring - corresponding to the sun's northward movement, and retreats southward in the autumn. The High's northward movement in spring and summer keeps storm systems farther north and tends to supress convective activity. It is thus the area's dry season. In the autumn and winter, the High moves southward allowing storm systems to come farther south affecting northern California and the Bay Area. This gives the region its rainy season. In summer the High in conjunction with the thermal low over the southwest U.S. and Mexico gives a steady flow from sea to land. This flow from moist ocean across cold coastal water creates the fog and stratus clouds that blanket the coastal areas and sweep in through the Golden Gate.

Topography and distance from the ocean greatly alter the climate over the state. Isotherms, rather than paralleling latitude lines, tend to follow height contours of the mountains around the central valley. The temperature range is greater also, as you move inland away from the moderating ocean effect. Though storm systems affect the northern part of the state more than the southern, elevation plays a considerable role in precipitation amounts. The higher elevations get precipitation for longer periods; windward exposures get greater amounts than do leeward areas. These elevations and distance-from-the-ocean effects can cause some sharp precipitation differences in short distances.

Variations from the usual climate conditions occur when the Pacific High builds farther north and east in either summer or winter. In summer this gives a wind flow from the interior of the Great Basin, bringing hot, dry conditions, and possibly upsetting the coastal upwelling. In winter the flow would be similar, but the Great Basin air would be much colder than normal, the diurnal temperature range greater, cloudiness could be decreased, and rainfall would be lessened because the storm tracks would be pushed farther north. These latter conditions seemed to be the case in the winter months in both 1984 and 1985.

3.2 Summary of Weather in 1985

The climatological conditions in the San Francisco Bay area are indicated by the precipitation, temperature, wind speed, and cloud cover data assembled from observations at San Francisco International Airport during 1985 (Table 3.1). Precipitation in 1985 was more than seven inches below the normal yearly amount, a very dry year. Observed and normal monthly precipitation during 1984 and 1985 at San Francisco airport are presented in Figure 3.1. The annual mean temperature was slightly warmer than normal. For the year, the winter months tended to be colder than normal and the summer months warmer than normal. The mean monthly average wind speed for 1985 was 0.6 mph greater than normal. Sky cover was less during the winter months but over the year showed no difference from normal. On a monthly basis, January stands out as exceptionally dry. December and April rank next, followed by February, October, and May. Only November, March, and June had more-than-normal precipitation, and then by less than an inch in each case.

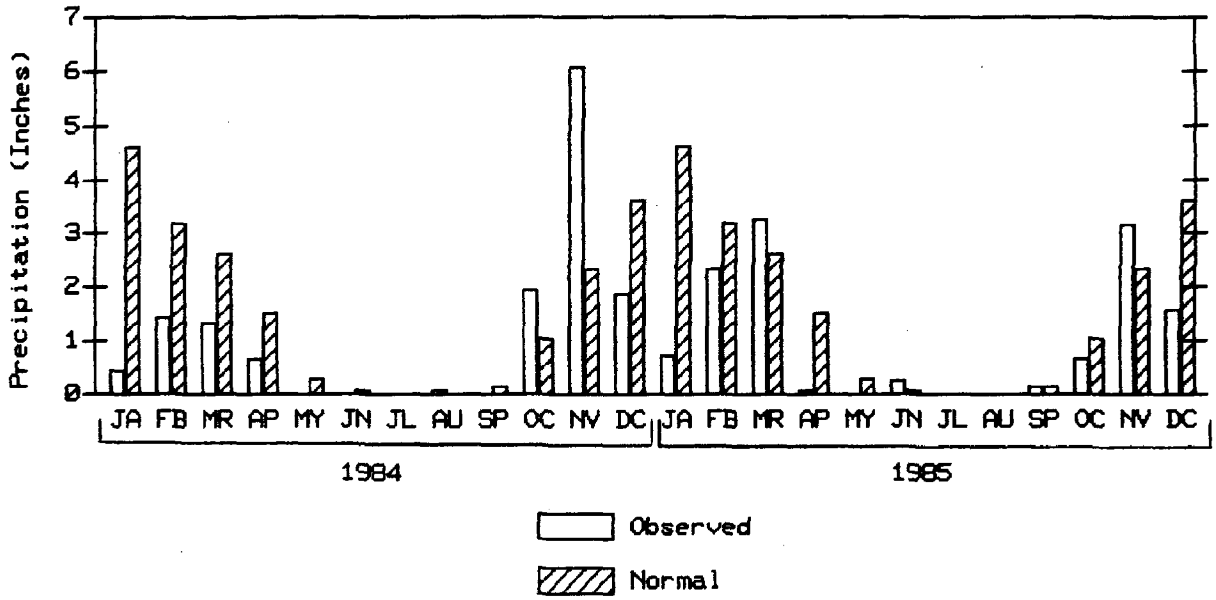
Table 3.1. Summary of climate conditions in the San Francisco Bay area during 1985. Normals are for the period 1951-1980. Data from NOAA, National Climatic Data Center.

	Precipitation (Inches)		Temperature (Deg. F)		Average Wind (MPH)		Mean Sky Cover (Tenths)	
Month	1985	Normal	1985	Normal	1985	Normal	1985	Normal
January	0.74	4.65	46.4	48.5	6.4	7.1	5.4	6.2
February	2.35	3.23	51.6	51.6	9.7	8.5	4.2	5.9
March	3.30	2.64	51.4	52.8	12.7	10.3	4.8	5.6
April	0.12	1.53	59.0	54.8	13.3	12.1	4.8	5.2
May	0.05	0.32	58.6	57.8	14.5	13.2	4.7	4.6
June	0.29	0.11	65.2	60.8	13.7	13.9	3.4	3.8
July	0.03	0.03	64.8	62.2	13.9	13.5	3.9	3.0
August	0.02	0.05	64.0	63.0	12.0	12.8	3.7	3.3
September	0.18	0.19	63.2	63.9	11.4	11.0	5.6	3.1
October	0.69	1.06	60.7	60.6	10.0	9.3	4.0	4.0
November	3.19	2.35	52.0	54.5	8.9	7.3	6.0	5.3
December	1.61	3.55	47.1	49.2	6.6	6.9	5.3	6.1
Annual	12.57 (Total)	19.71 (Total)	57.0 (Mean)	56.6 (Mean)	11.1 (Mean)	10.5 (Mean)	4.7 (Mean)	4.7 (Mean)

Locations of selected National Weather Service stations in the San Francisco Bay area and the Sacramento-San Joaquin drainage area are presented in Figures 3.2 and 3.3.

At San Francisco International Airport precipitation during 1985 fell short of the 1951 to 1980 normal by 36 percent. Though this is somewhat greater than at neighboring Bay Area stations, those in the Bay Area in Figure 3.2 had deficits for the year, ranging from 19 percent below normal at Mission Dolores within the city of San Francisco to 36 percent below at the Airport.

Within the Sacramento and San Joaquin river valleys, draining into the San Francisco Bay, dryness was equally prevalent during the year as all selected stations had precipitation deficits. It was most pronounced in the northern portion where deficits were as much as 58 percent below normal at McCloud. The least departure, 2 percent below normal, occurred at Fresno.



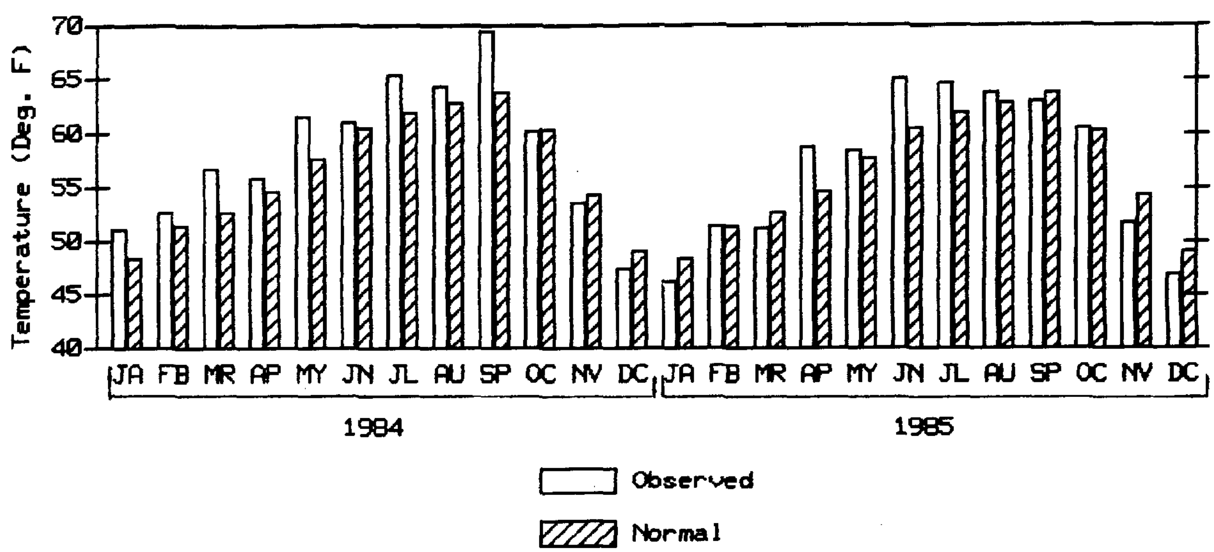


Figure 3.1 Observed and normal monthly total precipitation and mean air temperature values at San Francisco International Airport during 1984 and 1985. Data from NOAA, National Climatic Data Center.

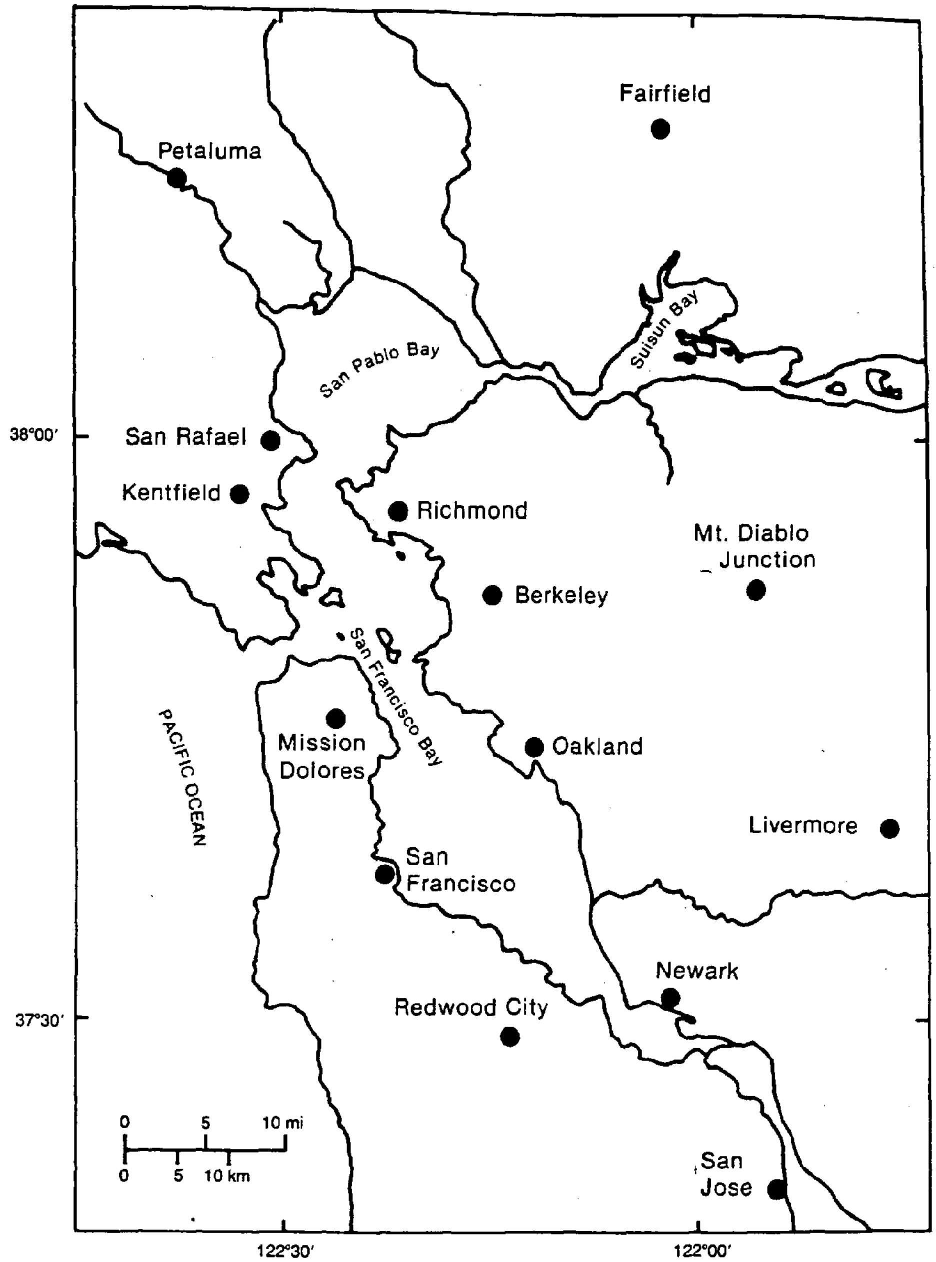


Figure 3.2 Meteorological stations, San Francisco Bay area.

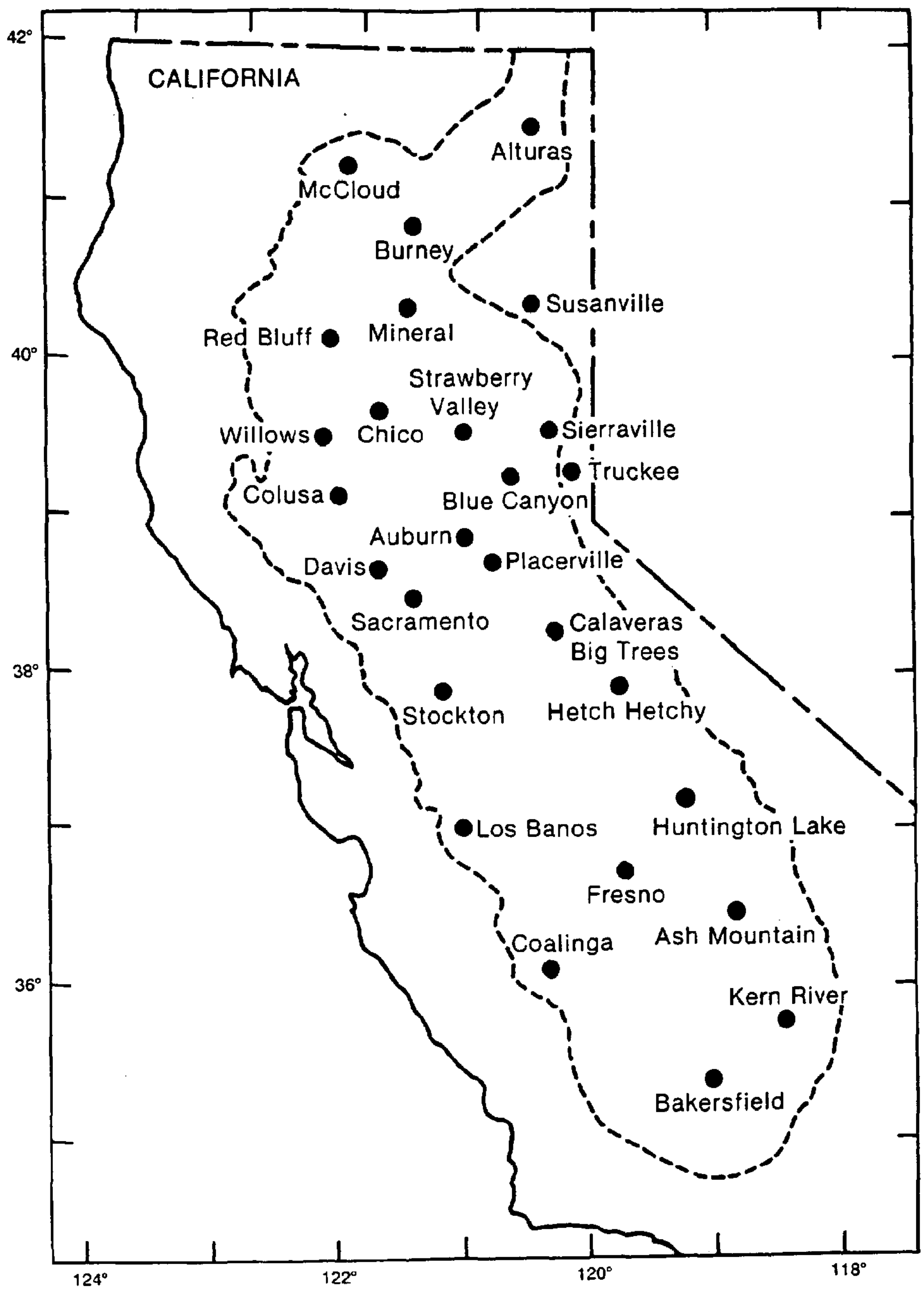


Figure 3.3 Meteorological stations, San Francisco Bay drainage basin.

In both the Bay Area and in the Central Valley the months of April, June, and July were clearly above normal in temperature with average departures of 3.9, 4.0, and 2.9°F above normal, respectively, in the Bay Area, and 5.2, 4.4, and 2.1°F above normal, respectively, in the Valley Region. The months of March, November, and September were below normal in temperature for all stations but one in the Bay Area. In the Bay Area the months of January and December were also clearly below normal, while the months of February, May, August, and October each were composed of a mixture of above- and below-normal temperatures. In the Valley, the months of January, February, May, August, October, and December had combinations of above- and below-normal temperatures with below-normal averages.

3.3 Storm Events and Impacts

The following is a summary of storm activity which occurred in Northern California and affected the San Francisco area during 1985. Table 3.2 is a summary of the significant storm events and impacts in Northern California in 1985.

January 1985 was a month in which little storm activity occurred in the San Francisco Bay area. Rainfall at San Francisco International Airport was only 0.74 inches for the month, compared to a normal receipt of 4.65 inches. The greatest daily amount was 0.47 inches on 7 January. Lowest sea level pressure for the month occurred the same day along with 16-mph southerly winds. Strong winds from an upper-atmosphere low-pressure system capping the Great-Basin high-pressure area downed trees in Yosemite National Park on 12 January.

In February a significant storm occurred on the 7th and 8th when 2.23 inches of rain fell in 24 hours and winds from the south southwest reached 35 mph at the San Francisco airport. Winds gusted to 59 mph at Angel Island. Pressure dropped to its lowest for the month during this storm, which brought a record 24-hour snowfall to Blue Canyon and produced snowdrifts of two to five feet elsewhere in the Sierras.

In March significant storms occurred on five occasions, beginning on the 2nd when 58-mph storm winds generated waves that sank a sea-going tug off Point Arena. Wind velocities reached 30 to 35 mph from the northwest at San Francisco International Airport on the 1st and 2nd. The area was swept by the south end of a storm off the Oregon-Washington coast from the 3rd to the 6th, which brought a thundershower to San Francisco and 2 to 4 feet of snow to the northern Sierra Nevada Mountains. After moderate rains on the 10th and the 17th a sizeable storm struck the entire West Coast on the 26th and 27th with winds which gusted to 90 mph in some areas of northern California and which brought 2 to 4 feet of snow to the mountains. Drifting snow closed roads and schools. Over an inch of rain fell amidst winds that reached 33 mph at the San Francisco airport on the 26th.

April at San Francisco and elsewhere in California was exceptionally dry. The only rain besides traces (less than 0.01 inch) fell on the 20th and 21st. Winds of 30 mph or more occurred on four occasions during the last half of the month. On one of these, 25 April, a multiple-car accident in which four people were killed, occurred in the lower Central Valley when visibility was reduced by dust from 50-mph winds.

Table 3-2.--Summary of storm events and impacts, Northern California, 1986. Data extracted from NOAA, National Climatic Data Center Storm Data summaries.

Date	Storm Event and Location	Impacts
January 12	Strong winds, Southern Sierra Nevada Mountains	Strong north to northeast winds raked the Sierra Nevada Range with gusts to 80 mph reported at Mammoth Mountain ski area. Some trees were blown down in Yosemite National Park.
February 8	Strong winds, San Francisco Bay	Strong, gusty southerly winds in the San Francisco Bay area with gusts to 59 mph recorded at Angel Island and 55 mph at Davis Point.
	Snowstorm, Sierra Nevada Mountains	Blue Canyon received a record 42 inches of snow in 24 hours. Two feet of snow with drifts to five feet were recorded in the Sierra Nevada Mountains causing all major highways there to be closed at one time or another.
March 2	Windstorm, Northern California coast	Thirty-foot seas produced by 58 mph winds sank a sea-going tug off Point Arena, 120 miles north of San Francisco.
March 3-6	Snowstorm, Sierra Nevada Range and northern mountains	Two to four feet of snow.
March 11	Tornado, Hollister	Minor damage to several commercial buildings.
March 26-27	Blizzard, Northern California mountains	One to three feet of snow and winds gusting to 90 mph forced the closing of schools and highways in northern mountain areas.
April 25	Windstorm, San Joaquin Valley	Northerly winds of up to 50 mph whipped up dust and reduced visibility to zero in the San Joaquin Valley, resulting in a 20-car accident in which 4 people were killed and 10 injured.
May 15	Strong winds, Red Bluff	A gust of wind destroyed a $20,000 canvas-topped stable and shed area at the Tehama County Fairgrounds.
June 2	Hail, western Kern County	Hail between 1/4 inch and 1/2 inch damaged approximately 300 acres of pistachios.
July 27	Lightning, Southern Sierra Nevada Mountains	Five hikers on the summit of Half Dome in Yosemite National were struck by lightning; 2 were killed and 3 were injured. A single hiker on Morr Rock in Sequoia National Park was killed by lightning.
September 10	Snowstorm, east side of Sierras	Six to 36 inches of snow fell in an early-season storm.
October 21	Snowstorm, Sierra Nevada Mountains	A strong early-season snowstorm brought heavy snow and strong gusty winds to the Sierras. Amounts from 6 inches to 2 feet fell in the 6000 to 7000 foot levels of the range.
November 10	Winter storm, all of Northern and Central California	One to two inch rainfall in lower elevations and very heavy snowfall in the Sierra Nevada Mountains came with a cold front from the Gulf of Alaska. Amounts up to 5 feet occurred above the 7000 foot level and amounts of about 2 feet fell between 5000 and 6000 foot levels.
November 29	Windstorm, San Franciso Bay	Wind speed of 46 mph occurred at San Francisco International Airport.
December 1	Windstorm, Northern California coast	Storm winds of 52 mph with gusts to 69 mph produced 20 to 35 foot combined wind waves and swells along the Northern California coast.

May continued to be below normal in precipitation and relatively uneventful. The average wind speed for the month, 14.5 mph, is slightly greater than the normal value of 13.2 mph. Cold fronts, associated with troughs or occasionally lows in wind flow at higher levels, continued to cross the Bay region, but rarely brought more than a trace of rain. These fronts were usually associated with stronger surface winds as higher pressure behind the front pushed inland. On the 15th strong winds behind a cold front destroyed a tent stable at the fairgrounds in Red Bluff.

Cold fronts, not readily distinguished, but associated with troughs and lows in the upper flow, crossed over the region six times during June. The little rain that fell in the state was mostly associated with instability from an upper-level low pressure system on the 1st and 2nd. Coastal stations north of the bay benefited considerably more from these rain producing systems.

In July an upper air trough on the 11th brought traces of precipitation to Northern California areas. A weak low pressure area in the upper atmosphere over central California on the 21st and 22nd brought precipitation to most areas of the State. Scattered precipitation occurred over the region from the 26th to the 31st. Lightning from thunderstorm activity in the southern Sierra Nevada mountains accounted for the deaths of three hikers and injury to three others on July 27th.

August was drier than July and had fewer weather events. A few showers occurred at the beginning of the month along the Northern California coast, followed by some isolated showers around the 7th. An upper-air trough brought showers to many areas on the 17th and 18th, and light precipitation associated with a cold front was reported from the 29th to the 31st over most of the region.

A persistent upper-air trough over the west coast during early September brought a series of cold fronts down the coast of Northern California. A cold front associated with a low pressure system from the 8th to the 10th brought an early season snow storm to the east side of the Sierras on the 10th. As much as three feet of snow fell at some mountain locations from this storm. Rains were frequent during the first half of the month.

During October measureable precipitation at San Francisco occurred in only one event. A strong cold front moved inland on the 20th and 21st bringing a total of 0.69 inches of rain to San Francisco. It brought heavy snow and strong gusty winds to portions of the Sierra Mountains. Strong winds locally, 30 to 35 mph on the 7th and 8th, followed a low pressure center which entered the area after migrating up the coast from off central Mexico.

A major winter storm accompanied a cold front on 10 November following earlier cold fronts on the 4th and the 8th. More cold fronts came on the 16th, 22nd, and 24th, the last bringing a large amount of rain to the area. On the 28th and 29th a storm system moved through the area bringing winds of 46 mph at San Francisco International Airport.

Winter storms from the Pacific crossed the Northern California coast on the 1st, 4th, 5th, and 7th. The storm on the 1st created 20 to 35 foot seas from winds of 52 mph with gusts to 69 mph off the Northern California coast. After the storm on the 7th the surface ridge off the West Coast built inland

and formed the Great-Basin high-pressure area which until the end of December effectively kept out further storms. A partial breakdown in the upper-atmospheric flow maintaining the surface high-pressure center in the Great Basin brought precipitation to much of California from the 29th to the 31st.

3.4 Wind and Fog

Wind is closely linked with other elements of weather and often serves as a critical component of their definitions. In Table 3.3 below are listed the average wind speeds in mph for each of the months of 1985 at San Francisco International Airport, the 1951 to 1980 normal monthly wind speeds for comparison, a listing of the number of days with fastest-mile wind speeds equal to or greater than 30 mph and 20 mph, and the fastest mile registered during the month along with its direction and date or dates of occurrence. Higher wind speeds during storms or for other reasons are frequently found at other locations in the Bay region depending on the alignment of the wind direction with a particular pass or strait.

Table 3.3. Wind at San Francisco Airport in 1985. Data from NOAA, National Climatic Data Center.

Month	Average wind speed (mph), 1985	Average wind speed (mph), 1951-80 normal	Days with wind speed at or exceeding 30 mph	20 mph	Fastest mile (mph) direction (Deg.), and date
January	6.4	7.1	0	2	24/310(31)
February	9.7	8.5	3	16	35/210(8)
March	12.7	10.3	6	24	35/300(1)
April	13.3	12.1	4	24	36/300(25)
May	14.5	13.2	5	28	33/290(3)
June	13.7	13.9	3	25	31/300(14)
July	13.9	13.5	3	29	32/290(9)
August	12.0	12.8	0	26	28/290(26)
September	11.4	11.0	1	23	30/280(15)
October	10.0	9.3	2	20	35/290(8)
November	8.9	7.3	2	13	46/270(29)
December	6.6	6.9	3	6	35/180(2)
Annual	11.1 (Mean)	10.5 (Mean)	32 (Total)	236 (Total)	46/270(29 NOV) (Fastest mile, direction, date)

Data in the table show all months except January, June, and August to have been windier than normal at San Francisco. The yearly average wind speed is 0.8 mph greater than the normal yearly average. The profile of average wind speeds seen here ought to be viewed in the context of its occurrence with somewhat warmer summer temperatures and colder winter temperatures in the Bay area and the pattern of dryness throughout the state, particularly during the winter.

The number or days with heavy fog in the San Francisco Bay compared with the 1951 to 1980 normal number of days is shown in Table 3.4 which follows. Only January has more days with heavy fog than the corresponding monthly mean. October has an equal number, and all the other months have fewer days. During the months of April through August fewer than 0.5 day of heavy fog should be expected during any given month.

Table 3.4. Number of days per month with heavy fog (visibility 1/4 mile or less) at San Francisco, 1985 and 1951 to 1980 normal. Dash indicates less than 0.5. Data from NOAA, National Climatic Data Center.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1985	6	2	0	0	0	0	0	0	0	2	1	2	13
Mean	4	3	1	-	-	-	-	-	1	2	3	4	19

3.5 Precipitation

January precipitation was almost uniformly low in the Bay area and in the inland valley region, with both areas averaging 84 percent below normal. Most rain came from a cold front around the 7th and from upper air troughs on the 26th and 28th. Much of the time the presence of high pressure inland maintained a flow of cold, dry air over the region.

February precipitation was greater, but more variable than that in January. In the Bay area it averaged 37 percent below normal, ranging from 19 percent above normal at Kentfield to 66 percent below normal at San Jose. In the inland valley region it averaged 50 percent below normal with a range from 24 percent below normal at the Truckee Ranger Station to 97 percent below normal at Coalinga (Tables 3.5 and 3.6). The first two weeks of the month were quite rainy. Most of the precipitation fell around the 2nd when a storm system came down the coast, and especially around the 7th and 8th when an even more vigorous storm developed along the northern California coast. A cold front on the 20th brought scattered additional precipitation to the area.

Precipitation in March averaged 46 percent above normal, ranging from 4 percent above at San Rafael to 70 percent above normal at Redwood City (Table 3.6). Within the drainage region inland, precipitation ranged from a high of 74 percent above normal at Willows to a low of 45 percent below normal at Bakersfield, averaging 16 percent above normal. Rainfall was frequent during the first twelve days of the month with greatest concentrations from the 4th to the 7th and again from the 10th to 11th. More rain occurred on the 17th and 18th. Cold fronts from the 24th to the 28th brought heaviest rains of the month to most of the region.

Measurable precipitation was very scarce in April despite the passage of eight fronts through the area. All stations listed in Table 3.6 had far below

Table 3.5 Normal monthly total precipitation (inches), selected meteorological stations, San Francisco area drainage basin. Data from NOAA, National Climatic Data Center.

Station	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual Total
Bay area stations													
Fairfield	5.11	3.27	2.54	1.43	0.36	0.15	0.04	0.10	0.27	1.26	2.64	3.77	20.94
Petaluma Fire Sta. 3	5.95	3.97	2.64	1.71	0.31	0.17	0.05	0.08	0.25	1.40	3.16	4.33	24.02
San Rafael Civic Cntr.	9.20	6.14	4.24	2.43	0.54	0.25	0.06	0.09	0.43	2.10	4.77	7.23	37.48
Kentfield	11.50	7.40	5.50	3.30	0.82	0.31	0.12	0.17	0.57	2.92	6.01	9.08	47.70
San Fran.Mission Dolores	4.48	2.83	2.58	1.48	0.35	0.15	0.04	0.08	0.24	1.09	2.49	3.52	19.33
San Francisco AP WSO	4.65	3.23	2.64	1.53	0.32	0.11	0.03	0.05	0.19	1.06	2.35	3.55	19.71
Redwood City	4.56	3.13	2.44	1.44	0.36	0.09	0.04	0.07	0.24	0.92	2.25	3.73	19.27
San Jose	3.00	2.23	2.03	1.19	0.30	0.07	0.05	0.13	0.21	0.67	1.71	2.27	13.86
Newark	3.17	2.10	1.81	1.18	0.33	0.11	0.04	0.08	0.19	0.70	1.83	2.43	13.97
Oakland WSO	4.03	2.79	2.32	1.47	0.37	0.13	0.05	0.05	0.26	1.12	2.26	3.18	18.03
Berkeley	5.30	3.51	2.97	1.95	0.40	0.17	0.07	0.11	0.36	1.25	2.93	4.22	23.24
Richmond	4.96	3.36	2.66	1.75	0.31	0.13	0.07	0.07	0.31	1.22	2.82	4.17	21.83
Mt. Diablo Junction	5.26	3.63	2.89	1.90	0.57	0.16	0.05	0.08	0.26	1.28	2.83	4.19	23.10
Livermore	3.04	2.19	1.81	1.28	0.38	0.11	0.04	0.07	0.18	0.67	1.77	2.57	14.11
Inland stations													
Alturas Rngr. Sta.	1.67	1.23	1.25	1.00	1.21	1.09	0.31	0.43	0.48	0.94	1.31	1.53	12.45
McCloud	10.17	8.01	6.03	3.65	2.04	0.91	0.27	0.56	1.06	2.95	6.96	8.65	51.26
Burney	5.57	3.93	3.02	1.91	1.26	0.88	0.12	0.37	0.73	1.74	3.33	5.20	28.06
Susanville	2.88	1.93	1.38	0.64	0.75	0.67	0.30	0.22	0.36	1.14	1.43	2.59	14.29
Mineral	10.47	7.69	6.10	3.94	2.28	1.37	0.20	0.74	1.18	3.86	6.74	8.88	53.45
Red Bluff WSO	4.50	3.31	2.39	1.51	0.77	0.43	0.06	0.21	0.46	1.16	3.10	3.59	21.49
Chico Univ. Farm	5.75	3.94	3.07	2.04	0.72	0.42	0.05	0.17	0.43	1.61	3.55	4.18	25.93
Sierraville Rngr. Sta.	5.46	3.75	2.90	1.56	1.35	0.60	0.32	0.42	0.52	1.97	2.99	4.73	26.57
Strawberry Valley	17.80	12.86	10.35	5.95	2.60	0.78	0.25	0.41	1.16	4.54	10.04	14.27	81.01
Willows	3.74	2.95	1.76	1.19	0.44	0.28	0.06	0.16	0.30	0.93	2.51	2.96	17.28
Truckee Rngr. Sta.	6.55	4.67	3.88	2.31	1.39	0.69	0.41	0.46	0.52	1.59	3.24	5.86	31.57
Blue Canyon WSO	14.11	9.93	8.96	5.45	2.70	0.86	0.30	0.55	0.97	3.93	8.41	11.70	67.87
Colusa	3.45	2.57	1.73	1.06	0.38	0.19	0.06	0.08	0.23	0.99	2.06	2.61	15.41
Auburn	7.49	4.99	4.71	2.97	1.07	0.31	0.15	0.15	0.46	2.01	4.43	5.72	34.46
Placerville	7.93	5.34	5.13	3.47	1.30	0.36	0.19	0.17	0.46	1.87	4.38	6.39	36.99
Davis Exp. Farm	4.12	2.85	1.97	1.22	0.35	0.12	0.03	0.05	0.21	0.95	2.17	3.10	17.14
Sacramento AP WSO	4.03	2.88	2.06	1.31	0.33	0.11	0.05	0.07	0.27	0.86	2.23	2.90	17.10
Calaveras Big Trees	10.94	8.00	7.42	5.00	1.85	0.64	0.19	0.30	0.73	2.38	5.94	9.37	52.76
Hetch Hetchy	6.33	5.18	4.63	3.58	1.66	0.89	0.20	0.38	0.65	1.52	4.04	5.86	34.92
Stockton WSO	3.02	2.03	1.81	1.36	0.30	0.08	0.05	0.07	0.23	0.62	1.77	2.43	13.77
Los Banos	1.76	1.62	1.14	0.84	0.24	0.04	0.02	0.04	0.22	0.47	1.17	1.44	9.00
Fresno WSO	2.05	1.85	1.61	1.15	0.31	0.08	0.01	0.02	0.16	0.43	1.24	1.61	10.52
Ash Mountain	5.00	4.11	3.84	2.86	0.91	0.25	0.06	0.11	0.50	0.86	2.61	4.29	25.40
Coalinga	1.65	1.55	0.94	0.66	0.24	0.02	0.01	0.02	0.25	0.25	0.99	1.25	7.83
Kern River Pwr. House 3	3.05	2.29	1.78	1.02	0.25	0.11	0.09	0.19	0.36	0.31	1.16	2.12	12.73
Bakersfield WSO	0.98	1.07	0.87	0.70	0.24	0.07	0.01	0.05	0.13	0.30	0.65	0.65	5.72

Table 3.6 Departure from normal monthly total precipitation, 1985 (percent), selected meteorological stations, San Francisco area drainage basin. Blanks indicate incomplete record. Data from NOAA, National Climatic Data Center.

Station	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual Total
<u>Bay area stations</u>													
Fairfield	-87	-40	63	-96	-94	-87	-100	-100	11	-48	64	-19	-27
Petaluma Fire Sta. 3	-80	-39	54	-84	-100	-94	20	-100	-68	-30	16	-20	-32
San Rafael Civic Cntr.	-87	-61	4	-88	-100	-100	-100	-100	-100		-76	-68	
Kentfield	-87	19	50	-89	-100	-48	-83	-100	4	-56	68	-36	-23
San Fran.Mission Dolores	-87	-30	53	-82	-74	107	-100	-100	58	-27	94	-30	-19
San Francisco AP WSO	-84	-27	25	-92	-84	164	0	-60	-5	-35	36	-56	-36
Redwood City	-86	-37	70	-94	25	67		-86	-25	8	28	-31	
San Jose		-66	47	-60	-23	-99	160	-99	67	46	44	-38	
Newark	-73	-50	34	-96	-24	-73	-25	-100	111	46	32	-20	-25
Oakland WSO	-88	-48	49	-95	-95	8	100	-98	15	-45	32		
Berkeley	-88	-33	45	-97	-95	-12	0	-99	47	11	46	-43	-30
Richmond	-84	-32	64	-94	-94		14	-100	13	1	72	-16	
Mt. Diablo Junction	-82	-35	39	-85	-84	125	-40	13	192	-38	13	-34	-32
Livermore	-84	-43	45	-75	-82	100	-98	-57	-28	33	52	-23	-24
Average (Bay area)	-84	-37	46	-88	-73	4	-19	-85	21	-10	37	-33	-28
<u>Inland stations</u>													
Alturas Rngr. Sta.	-69	-29	-38	-66	-21	-72	-84	-91	342	-84	90	-75	-28
McCloud	-96	-70	-35	-95	-89	-45	248	-46	206	-24	-66	-43	-58
Burney	-90	-65	-5	-92	0	-53	358	-84	349	-7	-6	-26	-32
Susanville	-75	-47	0	-98	-93	-100	-90	-100	67	-94	90	-56	-46
Mineral	-88	-52	-25	-87	-76	-91	-100	-86	375	-43	2	-46	-43
Red Bluff WSO	-86	-73	28	-97	-77	-93	483	-10	152	4	24	-33	-35
Chico Univ. Farm	-86	-69	16	-93	-100	-100	-100	-53	430	-58	48	-46	-37
Sierraville Rngr. Sta.	-88	-22	69	-90	-99	-67	91	-81	27	-41	43	-35	-30
Strawberry Valley	-87	-55	13	-74	-98	-87	-12	-63	222	-38	24	-48	-40
Willows	-86	-83	74	-61	-100	-100	-100	-56	173	-49	34	-30	-34
Truckee Rngr. Sta.	-91	-24	67	-90	-99	-35	54	-78	196	3	93	-39	-21
Blue Canyon WSO	-85	-35	12	-78	-98	-47	-83	-38	162	-42	45	-37	-34
Colusa	-74	-66	-4	-66	-100	-100	-100	50	509	-100	48	-30	-34
Auburn	-89	-37	24	-96	-100	-6	-87	27	322	-59	94	-29	-25
Placerville	-88	-36	19	-96	-100	25	-100	35	183	-21	82	-35	-29
Davis Exp. Farm	-75	-37	60	-72	-83	-25	-100	-80	67	-47	106	0	-13
Sacramento AP WSO	-84	-47	-2	-100	-97	36	-98	-14	107	-38	67	-19	-32
Calaveras Big Trees	-80	-34	25	-78	-100	41	74	-50	196	9	88	-31	-21
Hetch Hetchy	-83	-45	38	-72	-96	-66	-15	-79	194	74	23	-28	-27
Stockton WSO	-78	-58	22	-90	-100	175	0	-86	-70	102	41	-29	-30
Los Banos	-68	-78	-1	-94	-100	200	-95	-100	-95	2	155	-35	-26
Fresno WSO	-79	-62	7	-90	-100	313	300	0	169	98	144	-55	-2
Ash Mountain	-58	-29	38	-93	-97	-52	317	-100	116	149	121	-39	-11
Coalinga	-85	-97	35	-64	-100	-100	-100	1050	60	40	43	-46	-38
Kern River Pwr. House 3	-81	-36	48	-100	-100	-100	-56	-100	-50	-68	141	-32	-27
Bakersfield WSO	-61	-55	-45	-100	-42	529	-90	-100	85	-40	154	-58	-25
Average (Inland region)	-84	-50	16	-84	-86	-53	21	-62	205	-25	44	-37	-33

normal rainfall. At San Francisco measurable rainfall occurred only on the 20th and 21st under an upper-atmospheric trough. A trough on the 17th and 18th brought only traces of rain to San Francisco but brought measurable amounts to other stations in the area.

During May as in April cold fronts were frequent, but brought little precipitation. Rainfall amounts for the month in the Bay area averaged 73 percent below normal, ranging from no rain at three of the stations listed to 25 percent above normal at Redwood City, which received 0.31 inches on the 10th and 0.14 inches on the 29th. In the inland region draining into the San Francisco Bay 11 of the 26 stations listed received no rain in May. The average for the inland group was 86 percent below normal. In the Bay area measurable rain fell on the 10th from the passage of a cold front. Cold fronts were again active in the area from the 22nd to the end of the month during which time 0.09 inches fell in the city of San Francisco but only 0.01 inches fell at San Francisco International Airport.

From June through September throughout California little rainfall is expected, hence any amounts that do fall influence the totals strongly. Percentage departures may appear very large when actual receipts of rainfall have been quite small.

June precipitation averaged four percent above normal, ranging from no precipitation at San Rafael to 164 percent above normal at San Francisco International Airport. Similar variability was present inland where the average for the group of stations was 53 percent below normal. Precipitation generally came during the first week of June from the passage of an upper-atmospheric low-pressure center and two cold fronts. Part of the precipitation in the southern San Joaquin Valley came in the form of thundershowers which included hail. Traces of precipitation occurred around the 19th and 20th from the proximity of an upper-atmospheric low system.

In July, except for the moutainous parts of Northern California where a few tenths of an inch of rainfall are expected, most areas receive only a few hundredths of an inch of rain. In the Bay area monthly totals ranged from no precipitation at three stations to 160 percent above normal at San Jose with the average for the group being 19 percent below normal. In the inland valley portion seven of the stations reported no precipitation while five stations had amounts ranging from two to nearly five times normal. Their group average was 21 percent above normal. Rainfall during the month came around the 20th and 21st with isolated amounts around the 25th and 30th, due mainly to low-pressure centers aloft.

August precipitation is normally slightly greater than that in July but still very little. In the Bay area it was very dry indeed, averaging 85 percent below normal. Seven of the twelve Bay area stations had no rain at all and the rest were well below normal, except for Mt. Diablo Junction which had 13 percent above normal. The average of those in the Sacramento and San Joaquin Valleys was 62 percent below normal, ranging from no precipitation at five stations to 1050 percent above normal at Coalinga. Cold fronts around the 1st, 17th and 29th accounted for most of the rainfall.

In September rainfall came mainly from the 2nd to the 5th, on the 8th and 9th, and around the 18th from the passage of cold fronts with well established troughs or low pressure centers in the upper atmosphere. The frontal system on the 9th brought several inches to several feet of snow to the east side of the Sierra Nevada Mountains. In the Bay area precipitation amounts ranged from no rain at San Rafael to 192 percent above normal at Mt. Diablo Junction with the average for the group amounting to 21 percent above normal. Among the Valley stations amounts ranged from 95 percent below normal at Los Banos to 509 percent above normal at Colusa. Their average was 205 percent above normal.

October marked the beginning of the winter rainy season with the first major storm of the season on the 21st, though this was more apparent in the Sierra Nevada Mountains where strong gusty winds accompanied heavy snow than in the San Francisco Bay area. Despite this and despite bringing more actual rain than in September, October 1985 was still relatively dry. In the Bay area rainfall averaged 10 percent below normal with a range from 56 percent below normal at Kentfield to 46 percent above normal at both Newark and San Jose. In the Valley drainage region rainfall averaged 25 percent below normal and ranged from no rain at Colusa to 149 percent above normal at Ash Mountain. Cold fronts on the 6th and 7th and on the 20th and 22nd accounted for most of the rain during the month, the latter ones dominating in the north and along the coast while the earlier one provided a significant part of the rainfall to the Valley region.

November precipitation came mainly during the latter two-thirds of the month from a series of cold fronts punctuated by three storms. The first developed around the 9th and 10th and brought 2 to 5 feet of snow to the Sierra Nevada Mountains and rains of half an inch or more in the inland valleys. Cold fronts on the 16th and 20th added to these accumulations, but most rainfall came from storms on the 23rd and 24th and on the 28th and 29th. The storm on the 29th brought the strongest winds of the year to the Bay area. In the Bay area rainfall exceeded normal by an average of 37 percent with all but San Rafael having positive anomalies. San Rafael had 76 percent below normal for the month while Mission Dolores in San Francisco had 94 percent above normal for the month. In the inland valleys only two stations among the 26 were below normal for the month with an average of 44 percent above normal for the group and a range from 66 percent below normal at McCloud to 155 percent above normal at Los Banos. Both Fresno and Bakersfield in the southern San Joaquin Valley received more than double their normal rainfall.

During December precipitation occurred the first nine days, continuing the storminess of late November, and during the last three days when high pressure centered over the Great Basin since the 11th of December briefly broke down. From the 10th until the 28th very little rain fell, resulting in less than half the usual rainfall for much of the state. In the Bay area the stations in had from 68 percent below normal at San Rafael to 16 percent below normal at Richmond. The average for the group was 33 percent below normal. The inland stations averaged 37 percent below normal, ranging from 75 percent below normal at Alturas Ranger Station to exactly normal at Davis.

3.6 Air Temperature

Annual average temperatures for 1985 in the San Francisco Bay region were about equally divided between those ending the year with above-normal temperatures and those ending the year with below-normal temperatures (Tables 3.7 and 3.8). Their average of 0.2°F below normal does not include annual departures for Redwood City, San Jose, or Richmond. In the Central Valley region in Figure 3.3 the average of the departures is 0.5°F below normal.

January temperature departures from normal ranged from -6.5°F at Fairfield to -1.4°F at Oakland and averaged 2.8°F below normal. In the Valley temperature departures from normal ranged from -4.8°F at Bakersfield to +4.6°F at McCloud and averaged 1.0°F below normal.

February temperature departures from normal ranged from -0.4°F at San Rafael to +2.1°F at San Francisco Mission Dolores and at Livermore and averaged 0.5°F above normal. In the Valley, temperature departures from normal ranged from -5.4°F at Alturas to +3.1°F at Placerville and averaged 0.1°F below normal.

March temperature departures from normal ranged from -3.7°F at San Rafael to -0.8°F at Livermore and averaged 2.1°F below normal. In the Valley temperature departures from normal ranged from -4.8°F at Burney to -0.1°F at Huntington Lake and averaged 2.6°F below normal.

April temperature departures from normal ranged from +2.0°F at Berkeley to +5.8°F at Livermore and averaged 3.9°F above normal. In the Valley temperature departures from normal ranged from +2.8°F at Burney to +10.1°F at Blue Canyon and averaged 5.2°F above normal.

May temperature departures from normal ranged from -2.4°F at Redwood City to +1.5°F at San Francisco Mission Dolores and averaged 0.2°F below normal. In the Valley temperature departures from normal ranged from -2.9°F at Bakersfield to +3.3°F at Blue Canyon and averaged 0.2°F below normal.

June temperature departures from normal ranged from +0.6°F at Berkeley to +5.5°F at San Francisco Mission Dolores and averaged 4.0°F above normal. In the Valley temperature departures from normal ranged from +2.4°F at Bakersfield and at Strawberry Valley to +6.8°F at Fresno and averaged 4.4°F above normal.

July temperature departures from normal ranged from +0.7°F at San Jose to +5.6°F at San Francisco Mission Dolores and averaged 2.9°F above normal. In the Valley temperature departures from normal ranged from +0.1°F at Bakersfield and Strawberry Valley to +5.3°F at Placerville and averaged 2.1°F above normal.

August temperature departures from normal ranged from -1.5°F at Fairfield to +4.5°F at San Francisco Mission Dolores and averaged 0.2°F above normal. In the Valley temperature departures from normal ranged from -4.4°F at Burney to +1.6°F at Fresno and averaged 1.7°F below normal.

Table 3.7 Normal monthly mean air temperature (Degrees F), selected meteorological stations, San Francisco area drainage basin. Data from NOAA, National Climatic Data Center.

Station	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual Average
Bay area stations													
Fairfield	46.3	51.1	54.0	57.8	63.2	68.3	71.7	71.6	70.2	63.5	53.7	46.6	59.8
Petaluma Fire Sta. 3	47.1	50.8	52.3	55.0	59.2	64.1	67.0	67.3	67.0	61.8	53.7	47.5	57.7
San Rafael Civic Cntr.	49.5	53.1	54.8	57.5	61.5	65.7	67.8	67.8	67.8	63.5	56.0	50.3	59.6
Kentfield	46.7	50.7	52.8	55.9	60.3	64.9	67.0	66.6	65.9	60.9	53.1	47.5	57.7
San Fran.Mission Dolores	51.2	53.9	54.3	55.2	56.6	58.4	58.5	59.6	62.4	61.6	57.2	52.0	56.7
San Francisco AP WSO	48.5	51.6	52.8	54.8	57.8	60.8	62.2	63.0	63.9	60.6	54.5	49.2	56.6
Redwood City	48.7	52.0	54.1	57.2	61.6	65.9	68.4	68.1	67.0	61.6	54.5	49.2	59.0
San Jose	49.5	52.8	54.6	57.7	62.0	66.2	68.8	68.6	67.9	62.8	55.2	49.7	59.7
Oakland WSO	49.0	52.5	53.8	56.0	58.8	61.9	63.7	64.2	65.0	61.6	55.0	49.6	57.6
Berkeley	49.7	52.7	53.6	55.5	58.4	61.1	61.7	62.2	63.7	61.3	55.6	50.4	57.2
Richmond	49.7	53.3	54.8	57.1	60.0	62.3	62.4	63.2	65.1	62.5	56.1	50.5	58.1
Livermore	45.9	49.6	51.7	55.8	61.3	67.1	71.3	70.9	69.0	62.6	52.8	46.5	58.7
Inland stations													
Alturas Rngr. Sta.	28.9	34.0	37.5	43.4	51.4	59.1	65.9	64.0	57.7	48.1	37.9	31.2	46.6
McCloud	34.0	37.4	39.7	45.2	53.1	60.7	67.1	65.3	60.1	51.3	41.3	35.8	49.3
Burney	31.6	36.6	39.8	45.0	52.6	59.7	65.4	63.6	58.2	49.3	39.4	32.9	47.8
Susanville	30.1	35.4	39.9	46.2	54.4	62.5	69.5	67.1	60.5	50.1	39.2	31.2	48.8
Mineral	31.1	33.8	35.4	40.5	48.0	55.6	62.3	61.0	56.6	48.2	38.3	33.0	45.3
Red Bluff WSO	45.5	50.4	53.3	58.9	67.5	76.1	82.3	80.1	75.2	65.2	53.4	46.5	62.9
Chico Univ. Farm	44.8	49.5	52.6	57.8	65.8	73.0	78.1	76.4	72.1	63.2	52.2	45.5	60.9
Sierraville Rngr. Sta.	29.2	33.4	37.5	43.4	51.1	58.4	64.5	62.6	57.6	49.1	38.5	31.5	46.4
Strawberry Valley	38.8	40.8	41.9	46.8	54.4	62.3	69.2	67.9	64.2	55.5	45.3	40.6	52.3
Willows	44.7	49.5	52.8	58.2	66.1	73.3	77.8	75.9	72.3	64.1	52.8	45.5	61.1
Truckee Rngr. Sta.	25.8	28.9	32.1	38.3	46.3	54.0	61.2	59.6	54.6	45.8	35.3	27.8	42.5
Blue Canyon WSO	37.1	38.1	38.2	43.3	51.5	60.1	68.3	66.9	62.8	54.2	44.3	39.5	50.4
Colusa	45.0	50.2	53.3	58.7	66.6	73.3	77.5	75.9	71.8	63.0	52.0	45.3	61.1
Auburn	44.8	48.6	50.9	55.8	62.6	70.5	77.2	76.1	71.8	63.4	52.7	45.9	60.0
Placerville	41.1	44.5	47.1	51.9	59.0	66.6	73.5	72.1	67.1	58.0	47.7	42.0	55.9
Davis Exp. Farm	45.1	50.0	53.0	57.7	64.4	70.9	74.3	73.1	70.4	63.2	52.8	45.7	60.1
Sacramento AP WSO	45.3	50.3	53.2	58.2	64.9	71.2	75.6	74.7	71.7	63.9	53.0	45.6	60.6
Calaveras Big Trees	36.4	38.2	39.4	43.8	51.3	59.6	66.9	65.6	61.1	52.8	43.1	38.0	49.7
Hetch Hetchy	38.0	41.6	43.6	48.9	56.0	63.4	70.6	69.7	65.2	56.9	45.9	39.2	53.3
Stockton WSO	45.2	50.3	53.7	59.0	66.3	73.1	78.0	76.8	73.1	64.6	53.3	45.5	61.6
Huntington Lake	32.5	33.1	33.2	37.4	44.4	53.0	60.6	59.7	55.2	47.4	39.1	34.3	44.2
Los Banos	45.5	50.7	54.5	59.8	66.4	72.9	78.3	76.8	72.7	64.4	53.2	45.7	61.7
Fresno WSO	45.5	50.5	54.3	60.1	67.7	75.0	81.0	78.9	74.1	64.8	53.2	45.3	62.5
Coalinga	46.2	50.8	54.1	59.7	67.6	75.1	81.5	79.6	74.3	64.9	53.4	46.4	62.8
Kern River Pwr. House 3	45.6	48.8	51.6	57.3	65.3	73.9	81.3	79.8	74.7	64.3	53.0	46.4	61.8
Bakersfield WSO	48.2	53.2	57.1	62.7	70.6	78.3	84.5	82.4	77.3	68.0	56.2	48.2	65.6

Table 3.8 Departure from normal monthly mean air temperature (Degrees F), 1985, selected meteorological stations, San Francisco area drainage basin. Blanks indicate incomplete record. Data from NOAA, National Climatic Data Center.

Station	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual Average
<u>Bay area stations</u>													
Fairfield	-6.5	0.0	-3.3	3.9	0.8	5.2	3.8	-1.5	-2.8	-2.5	-6.2	-7.4	-1.3
Petaluma Fire Sta. 3	-3.1	0.4	-1.6	4.5	-1.0	3.3	1.8	-1.1	-3.3	-1.0	-3.8	-3.1	-0.6
San Rafael Civic Cntr.	-5.6	-0.4	-3.7	2.9	-1.9	3.8	1.2	-1.2	-4.2	-2.5	-5.4	-6.3	-1.9
Kentfield	-2.3	1.3	-1.6	5.1	1.3	5.2	4.8	2.3	0.0	1.3	-2.1	-2.4	1.1
San Fran.Mission Dolores	-1.2	2.1	-1.1	4.6	1.5	5.5	5.6	4.5	1.7	1.6	-2.2	-0.7	1.9
San Francisco AP WSO	-2.1	0.0	-1.4	4.2	0.8	4.4	2.6	1.0	-0.7	0.1	-2.5	-2.1	0.4
Redwood City	-2.3	-0.2	-2.6	3.8	-2.4	3.3	-0.6		-2.8	-1.0	-3.3	-2.5	
San Jose		-0.3	-3.2	4.0	0.4	5.3	3.8	0.9	-0.9	0.0	-3.0	-2.3	
Oakland WSO	-1.4	0.3	-1.4	2.8	-0.3	2.1	0.7	-1.2	-2.3	-2.0	-1.7	-0.8	-0.4
Berkeley	-2.3	0.1	-3.2	2.0	-1.9	0.6	1.0	-0.5	-2.9	-1.6	-4.7	-2.7	-1.4
Richmond	-2.4	0.8	-1.4	3.3	-0.1		2.8	0.9	-1.0	-0.1	-3.8	-1.6	
Livermore	-1.9	2.1	-0.8	5.8	0.2	5.2	3.6	-0.5	-2.4	-0.1	-2.7	-1.7	0.6
Average (Bay area)	-2.8	0.5	-2.1	3.9	-0.2	4.0	2.9	0.2	-1.8	-0.6	-3.5	-2.8	-0.2
<u>Inland stations</u>													
Alturas Rngr. Sta.	-0.7	-5.4	-4.1	3.2	-1.2	3.7	3.1	-2.3	-5.4	-3.8	-11.0	-3.0	-2.2
McCloud	4.6	0.2	-0.9	6.9	1.7	5.5	4.0	-0.4	-3.8	-2.1	-6.4	3.8	1.0
Burney	-1.6	-2.8	-4.8	2.8	-2.1	3.0	0.7	-4.4	-6.4	-5.0	-8.4	-4.1	-2.7
Susanville	-4.4	-3.6	-2.9	4.2	-0.1	4.3	2.6	-1.2	-5.2	-1.4	-7.5	-3.2	-1.5
Mineral	0.9	-2.3	-3.2	3.3	-1.9	3.3	0.9	-3.2	-7.8	-4.1	-7.2	0.3	-1.7
Red Bluff WSO	0.1	2.9	-1.2	5.6	0.9	5.7	1.2	-2.7	-5.7	-1.3	-5.1	-2.5	-0.2
Chico Univ. Farm	-3.4	-0.1	-3.2	3.3	-1.2	2.8	0.7	-4.1	-4.1	-1.2	-3.8	-3.8	-1.5
Sierraville Rngr. Sta.		-4.0	-3.9		-1.2	3.9	0.4	-2.8	-5.3	-3.9	-8.9	-3.1	
Strawberry Valley	1.0	-1.0	-4.3	4.0	-1.7	2.4	0.1	-2.7	-8.2	-2.0	-6.0	2.6	-1.3
Willows	0.1	2.8	-2.5	4.2	-2.8	4.2	1.3	-2.7	-4.0	-0.2	-3.3	-3.2	-0.5
Truckee Rngr. Sta.	0.6	0.5	-1.5	6.4	1.7	6.2	2.9	0.9	-4.1	-1.3	-4.1	-1.0	0.6
Blue Canyon WSO	3.8	2.6	-1.5	10.1	3.3	5.8	1.1	-1.5	-8.4	-1.6	-6.8	4.2	0.9
Colusa	-2.1	0.3	-2.4	4.6	-0.9	3.5	1.9	-2.2	-4.5	-0.6	-2.9	-2.1	-0.7
Auburn	-2.7	1.5	-3.6	5.2	-0.1	4.6	2.8	-2.8	-5.9	-2.0	-4.7	-0.8	-0.7
Placerville	0.7	3.1	-2.6	5.4	-0.3	5.1	5.3	1.2	-3.8	1.8	-1.5	4.2	1.5
Davis Exp. Farm	-4.3	0.0	-3.2	4.8	-0.9	4.0	2.4	-2.1	-3.3	-0.9	-3.9	-4.7	-1.1
Sacramento AP WSO	-2.9	1.1	-2.4	3.3	-1.7	3.9	1.4	-1.8	-3.2	-0.6	-3.2	-3.0	-0.7
Calaveras Big Trees	-0.3	-1.9	-3.9	6.5	1.3	5.3	2.8	-0.3	-6.9	-2.6	-6.3	0.5	-0.5
Hetch Hetchy	0.7	-0.5	-3.2	6.1	0.6	3.9	1.4	-1.2	-6.4	-1.8	-5.1	0.9	-0.4
Stockton WSO	-3.8	-0.1	-4.0	3.0	-2.2	2.8	0.3	-3.2	-5.0	-1.7	-2.9	-4.4	-1.8
Huntington Lake	2.2	2.6	-0.1	7.0	1.6	5.8	3.4	0.2	-6.2	-2.1	-3.2	3.5	1.2
Los Banos	-4.0	1.0	-0.9	4.8	0.5	4.3	2.7	-1.2	-2.2	-0.3	-1.7	-4.5	-0.1
Fresno WSO	-2.2	0.8	-1.2	7.1	1.7	6.8	5.0	1.6	-1.8	0.2	-0.7	-1.5	1.4
Coalinga	-2.9	0.1	-1.8	6.9	1.1	5.4	3.2	-0.6	-3.3	-1.1	-0.6	-2.7	0.3
Kern River Pwr. House 3	1.0	0.7	-1.0	7.3	0.8	5.1	1.7	-0.6	-5.4	-0.9	-3.2	2.2	0.7
Bakersfield WSO	-4.8	-1.3	-3.2	3.2	-2.9	2.4	0.1	-3.4	-6.5	-3.4	-3.0	-4.9	-2.3
Average (Inland region)	-1.0	-0.1	-2.6	5.2	-0.2	4.4	2.1	-1.7	-5.1	-1.7	-4.7	-1.2	-0.5

September temperature departures from normal ranged from -4.2°F at San Rafael to +1.7°F at San Francisco Mission Dolores and averaged 1.8°F below normal. In the Valley, temperature departures from normal ranged from -8.4°F at Blue Canyon to -1.8°F at Fresno and averaged 5.1°F below normal.

October temperature departures from normal ranged from -2.5°F at Fairfield and San Rafael to +1.6°F at San Francisco Mission Dolores and averaged 0.6°F below normal. In the Valley, temperature departures from normal ranged from -5.0°F at Burney to +1.8°F at Placerville and averaged 1.7°F below normal.

November temperature departures from normal ranged from -6.2°F at Fairfield to -1.7°F at Oakland and averaged 3.5°F below normal. In the Valley temperature departures from normal ranged from -11.0°F at Alturas to -0.6°F at Coalinga and averaged 4.7°F below normal.

December temperature departures from normal ranged from -7.4°F at Fairfield to -0.7°F at San Francisco Mission Dolores and averaged 2.8°F below normal. In the Valley, temperature departures from normal ranged from -4.9°F at Bakersfield to +4.2°F at Blue Canyon and at Placerville and averaged 1.2°F below normal.

The annual average temperature departures from normal ranged from -1.9°F at San Rafael to +1.9°F at San Francisco Mission Dolores and averaged 0.2°F below normal. In the Valley, temperature departures from normal ranged from -2.7°F at Burney to +1.5°F at Placerville and averaged 0.5°F below normal.

4. OCEANOGRAPHY AND HYDROLOGY

4.1 Streamflow

Freshwater inflow is important to an estuary for a variety of reasons. It influences the salinity regime, the circulation pattern, the sediment and nutrient distributions, phytoplankton and migratory fish dynamics, the dilution and dispersion of wastes and toxics, erosion patterns, flooding characteristics, and the general estuarine habitat.

The drainage basin of San Francisco Bay, California's Central Valley, covers more than 40 percent of the land area of California. Due to the large number of small streams and the multiple diversions made from the major rivers in the region the hydrology of the San Francisco Bay area is extremely complex. Water is diverted from the Sacramento and San Joaquin Rivers for industrial, agricultural, and residential uses. Nonetheless, the freshwater inflow into the bay is dominated by the outflow from the Delta which is formed by the confluence of these two rivers. This merging is directly east of the point at which the waters flow into Suisun Bay (Figure 4.1). The Delta, a 700 mile network of dredged freshwater channels, is an area from which water is pumped south for delivery to the San Joaquin Valley and southern California. Nearly 90 percent of all freshwater entering the Bay is discharged through the Delta. There are also numerous local streams flowing directly into the Bay. Some of these are the Napa River, Sonoma Creek, Alameda Creek, and Coyote Creek (Table 4.1).

Table 4.1. Average annual flows in some streams tributary to San Francisco Bay.

Stream	Average annual flow (cubic feet per second)
Sacramento-San Joaquin River	23,000
Napa River	149
Alameda Creek	121
Sonoma Creek	69
Coyote Creek	61

Data from California State Water Resources Control Board, 1975.

Because of the upstream impoundment of the rivers and the multiple diversions of water from the Sacramento-San Joaquin River system, evaluating streamflow as freshwater input to the Bay is difficult. However, various agencies have developed formulas for estimating the Delta outflow. These formulas use various combinations of gauged, calculated, and estimated data to arrive at outflow figures.

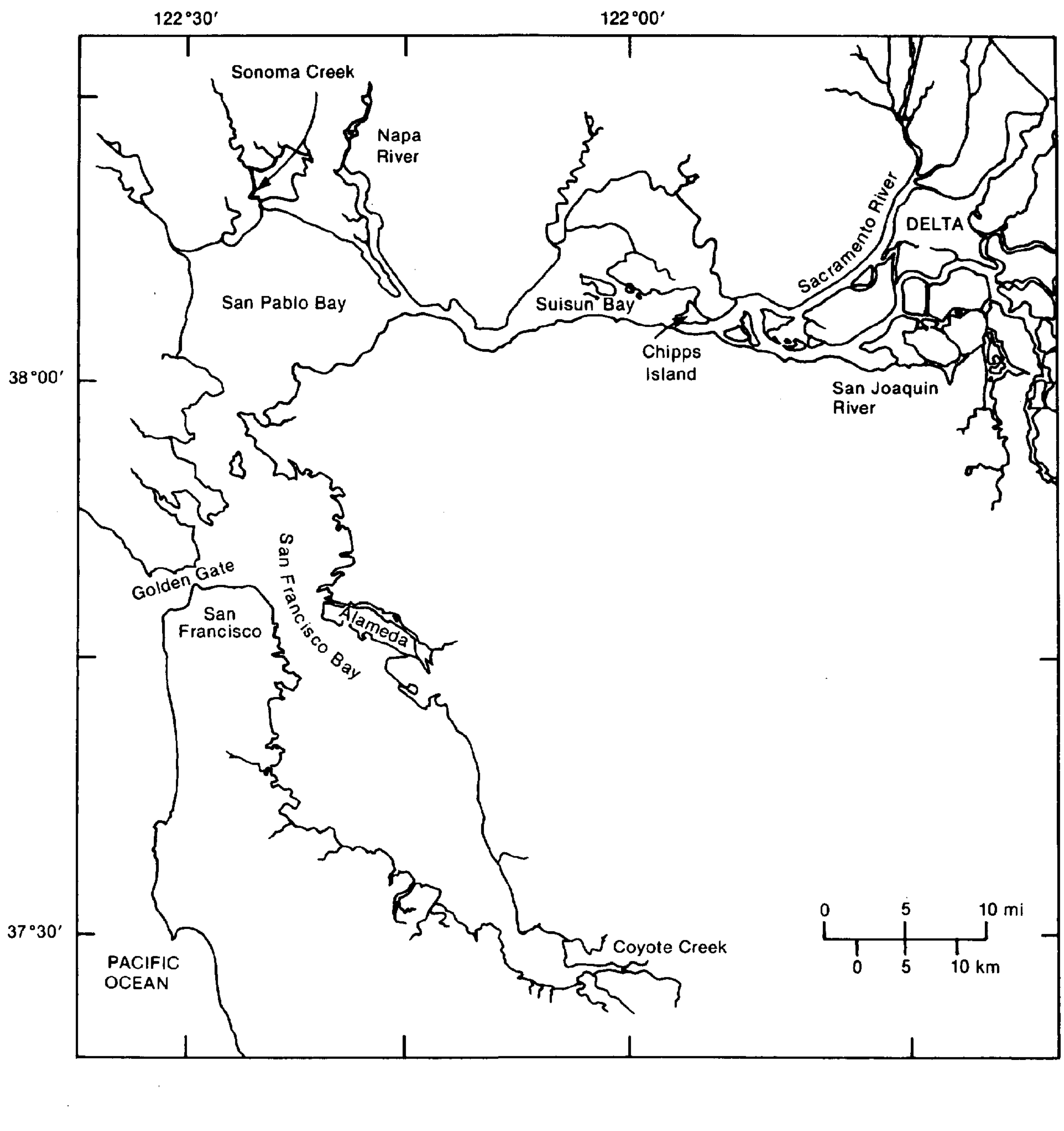


Figure 4.1 The San Francisco Bay Estuary. Note the locations of the Delta and Chipps Island. Modified Department of Interior map.

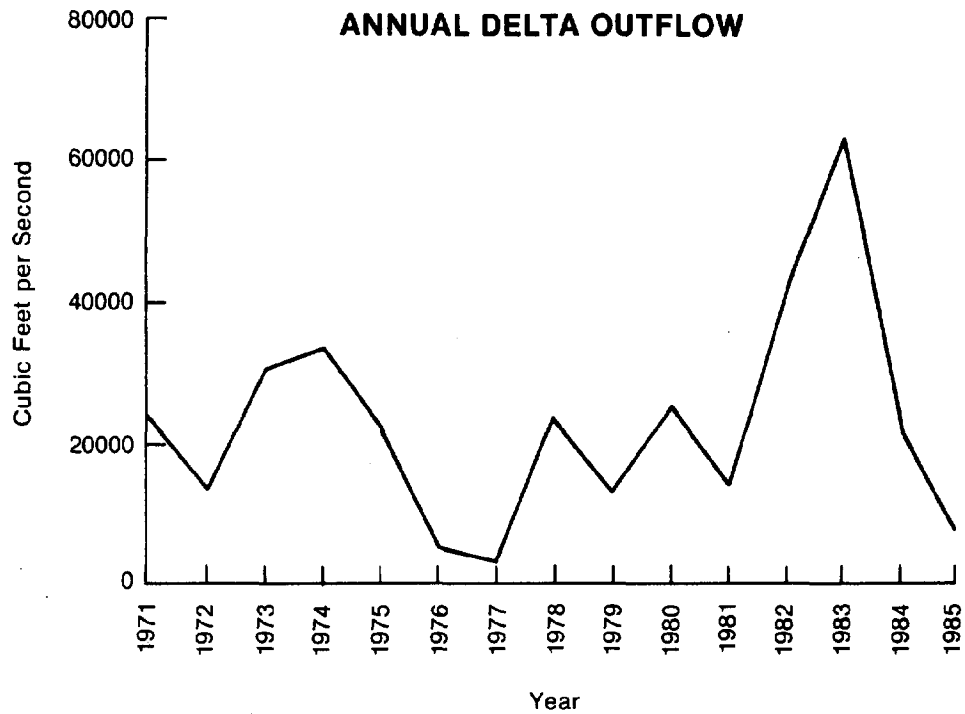


Figure 4.2 Mean annual Delta outflow at Chipps Island. Data from the California Department of Water Resources Operations and Maintenance.

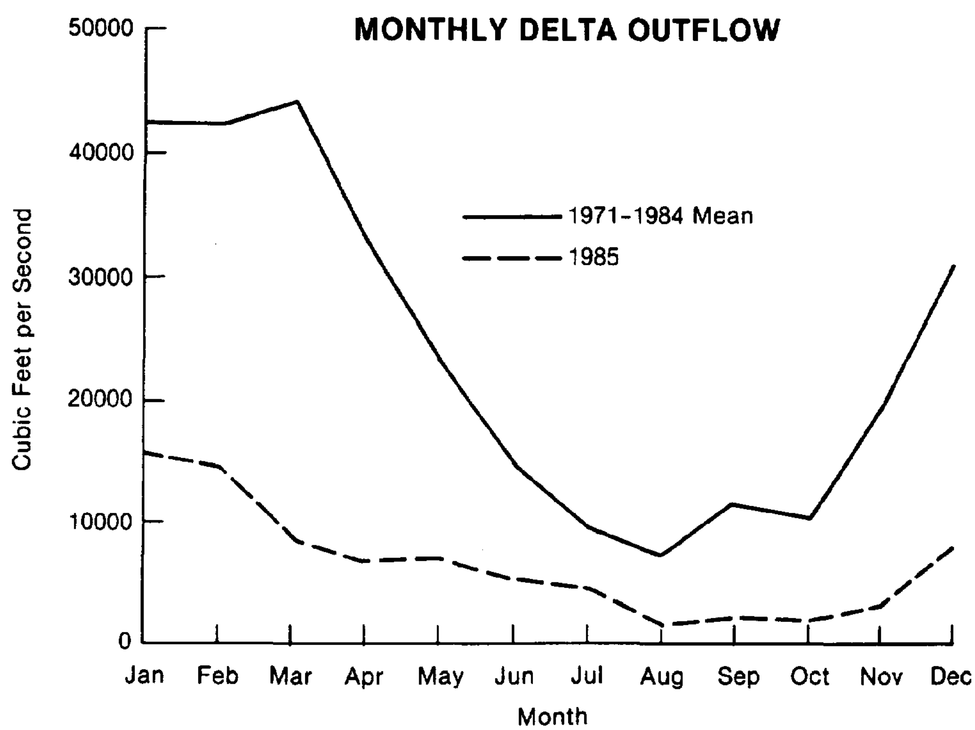


Figure 4.3 Mean monthly Delta outflows 1971-1984 mean and 1985. Data from the California Department of Water Resources Operations and Maintenance.

The State of California's Department of Water Resources Operations and Maintenance staff uses an algorithm that calculates net Delta outflows at Chipps Island. These outflows are used as the flow values into San Francisco Bay. The outflow is defined as follows:

Net Delta Outflow =

  Sacramento River flow at Freeport
+ San Joaquin River flow at Vernalis
+ Sacramento Treatment Plant discharge
+ Byron-Bethany Irrigation District diversion
- Central Valley Project Tracy pumping plant
- Contra Costa Canal pumping plant
- Clifton Court Forebay inflow
- Net consumptive use estimate

Calendar year means of these data are represented in Figure 4.2. Flow was a record high in 1983, declined through 1984, and was a near-record low in 1985. Except for the flow during the drought years of 1976 and 1977, the Delta outflow in 1985 was the lowest for the period from 1971 to 1984.

The mean monthly outflows for 1985 and 1971-1984 are shown in Figure 4.3. Normally the highest outflows occur from December to April and the lowest flows during the summer months. The historical peak volume in March is the result of a combination of high winter precipitation and snowmelt. Similarly, the long-term minimum in the summer can be related to low long-term precipitation values. Although the 1985 data followed this general pattern, the rates were much lower. This can be directly associated with the well-below normal rainfall across the California Central Valley throughout 1985 (See Section 3.2).

The exact relationships between streamflow and the environmental factors it affects are not quantifiable, but some relative conclusions can be made. The low flow in 1985 probably reduced the sediment loading of the Bay. This, coupled with the altered circulation accompanying the low flow, might have changed the sediment and phytoplankton distributions. Salinities were much higher due to the reduced flow (See Section 4.3). The low 1985 flow rates reduced the diluting and flushing strength of the Bay waters, perhaps resulting in an increase in the concentration of pollutants in the incoming waters.

4.2 Bay water temperature

Water temperatures in an estuary such as San Francisco Bay influence the timing of marine species' life stages and biological productivity in general. Temperatures throughout the Bay vary with the season. During the summer, water is usually warmer than the ocean in the northern reaches of the Bay toward the Delta, due to both atmospheric heating and the influx of warm river water. In the winter, the opposite distribution is found, since the river water and the air are usually cooler than the ocean. In the South Bay, which has relatively low fresh water influx, the temperatures are intermediate between ocean and river temperatures.

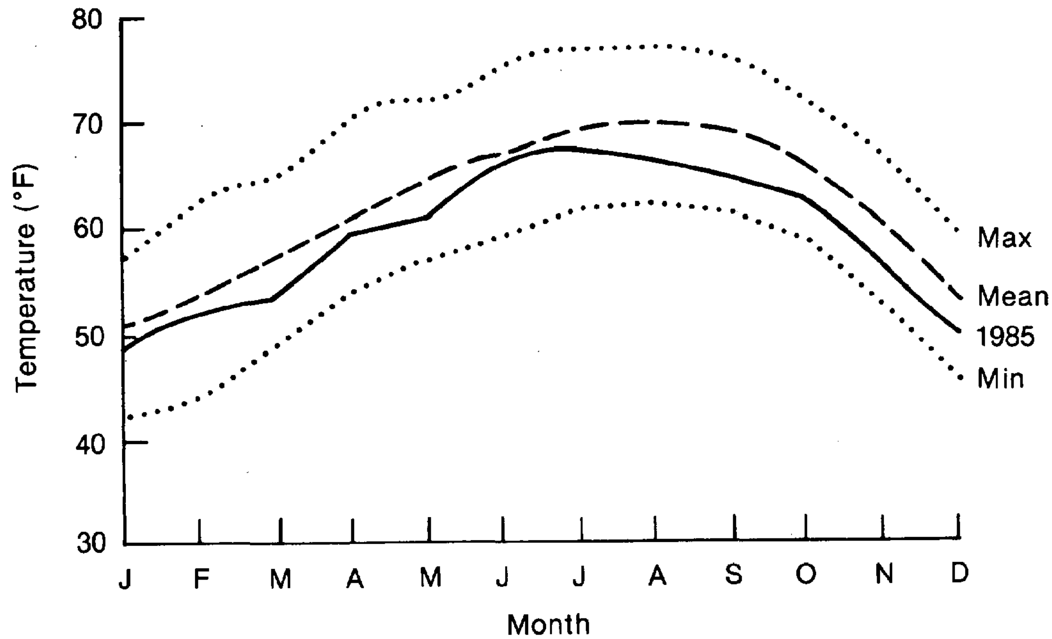


Figure 4.4a Monthly progression of mean surface water temperatures at Alameda.

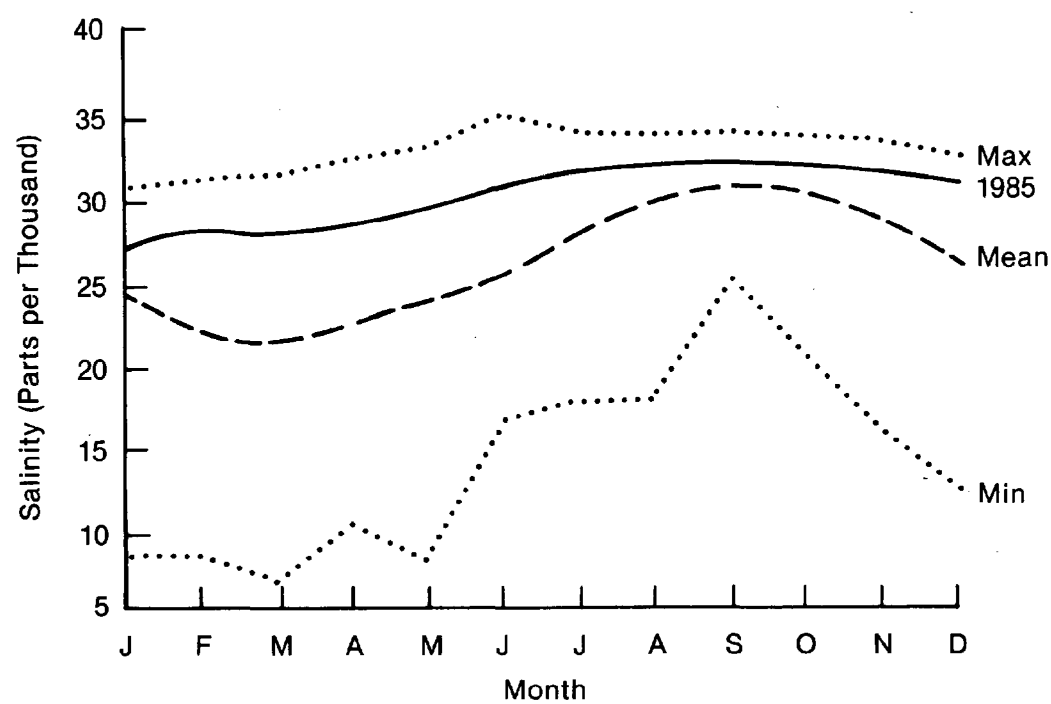


Figure 4.4b Monthly progression of mean surface water salinities at Alameda.

Monthly mean temperatures were 1 to 4°F cooler than the normal, possibly due to the greater-than-average wind speeds in the area (Table 3.3) which would cause both increased evaporative cooling in the summer, and stronger vertical mixing of the deeper, cooler Bay waters into the surface layers. In the summer, reduced freshwater inflow may allow more oceanic water in, which has a considerably lower temperature than the Bay. air temperatures were warmer than normal from April through August (Figure 3.1), which probably moderated the effect. Figure 4.4a shows the monthly progression of water temperature at Alameda.

4.3 Salinity

Salinity distribution in a estuary determines, in part, the location of zones of biological productivity. In San Francisco Bay, the high salinity waters of the Pacific Ocean are mixed with the fresh waters from the Delta to form an estuarine zone of brackish water, most noticeable in the upper Bay.

During 1985, the Delta discharge was quite low (Figure 4.3), resulting in higher than normal salinities in the Bay. Figure 4.4b shows the monthly progression of mean surface salinities measured at Alameda. Monthly means were 3 to 6 parts per thousand higher than normal, and approached the maximum values observed over the period of record.

Although no measurements are yet available, the low river flow in 1985 would tend to give relatively uniform salinity and temperatures over depth, especially in the spring, when stronger than normal winds occurred (Table 3.3).

4.4 West Coast Sea Surface Temperature Anomalies

Sea Surface Temperature (SST) anomalies for the west coast of the U.S., Canada, and Baja California are discussed in this section. The regional approach is given since variations in surface water temperatures possibly results in shifting the location of fisheries either up or down the coast to the fisheries preferred temperature ranges. The data source is the Oceanographic Monthly Summary produced jointly by the National Weather Service and the National Environmental Satellite, Data, and Information Service of NOAA. The monthly charts of sea surface temperature anomalies produced from gridded 1° square data were recontoured using as the first contour interval an anomaly value of +/- 0.5°C (Figure 4.5). Temperatures between +0.5 and -0.5°C were considered near-normal temperatures. A monthly description of the major anomaly features discussed in the following paragraphs.

Warmer-than-normal temperatures were observed for most of the Gulf of Alaska as well as the California coast in January 1985. The warmer temperatures within the Gulf of Alaska could have resulted from the augmented wind-induced northward transport of North Pacific West-Wind Drift waters during January 1985. Normal temperatures prevailed south of 45°N latitude while warmer temperatures were to the north. Normal temperatures were observed for the near coastal (1 - 2) grid squares for Oregon and Washington States and Vancouver and Queen Charlotte Islands. Several pools of cooler water were offshore of California and closer to shore off Baja California.

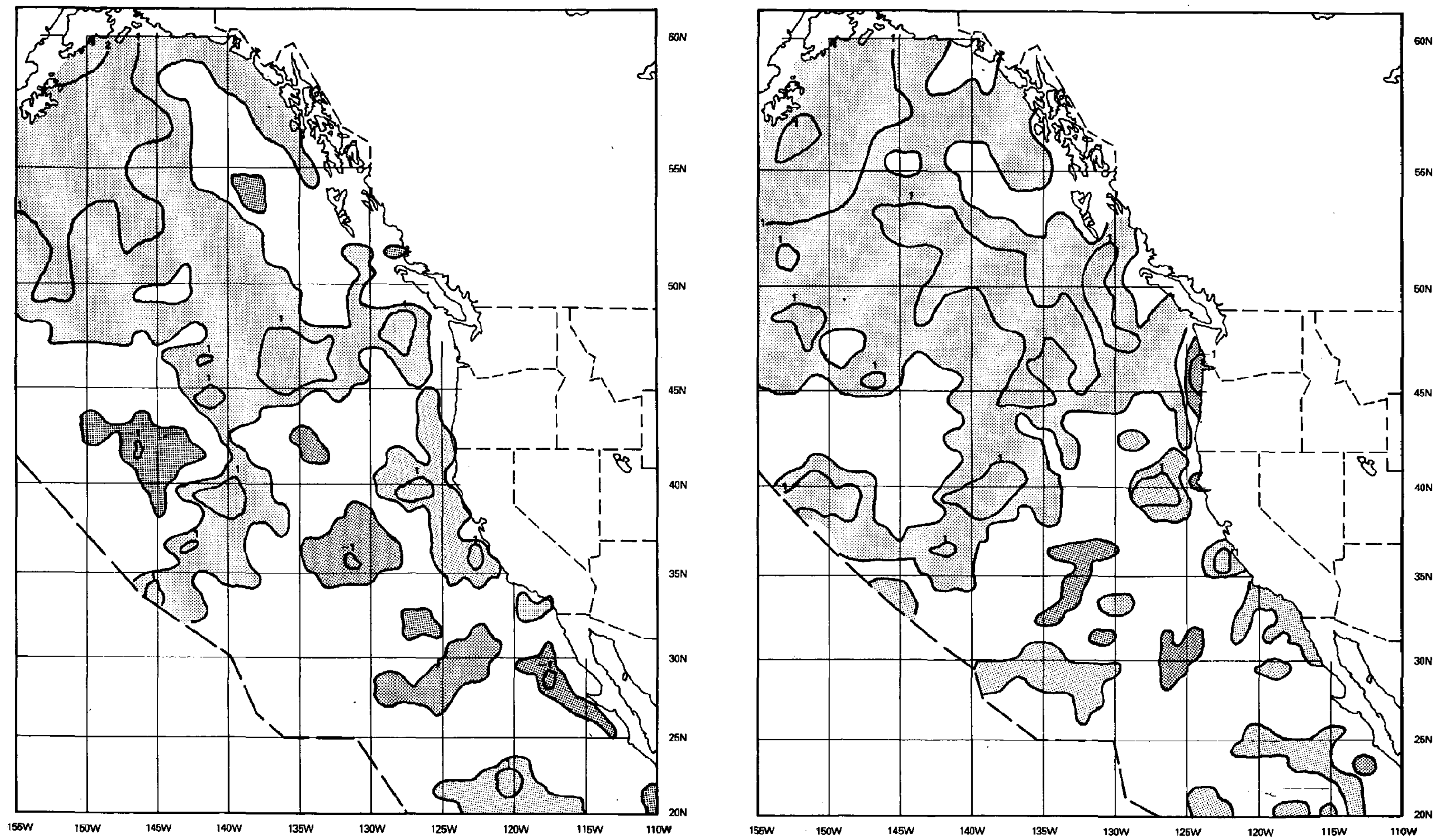


Figure 4.5a Monthly sea surface temperature anomaly. Contour interval $\pm$ 0.5°C. Light stippling - positive anomaly; dark stippling - negative anomaly. January, February 1985.

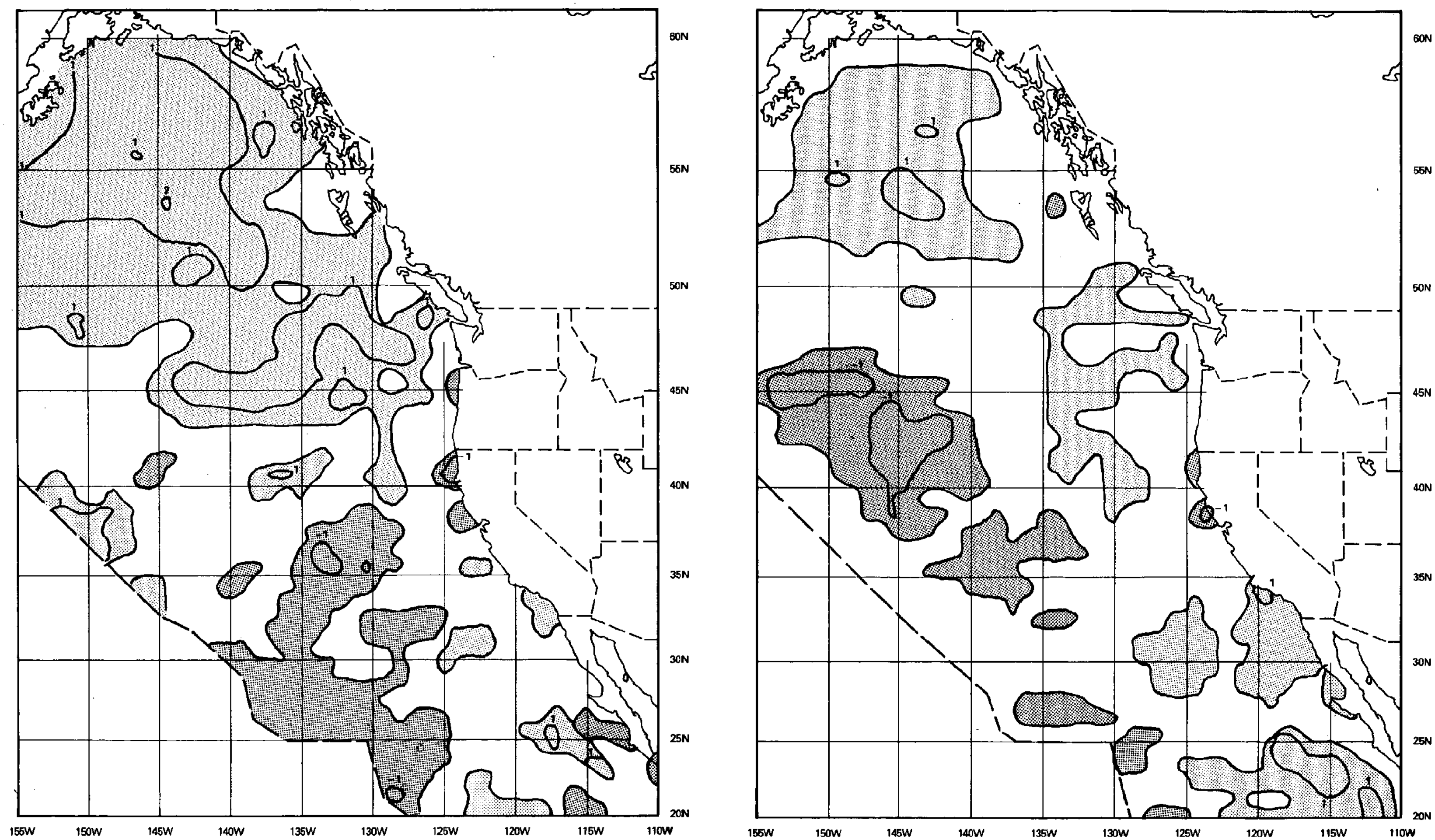


Figure 4.5b Monthly sea surface temperature anomaly. Contour interval $\pm$ 0.5°C. Light stippling - positive anomaly; dark stippling - negative anomaly. March, April 1985.

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL ENVIRONMENTAL SATELLITE, DATA, AND INFORMATION SERVICE
Washington, D.C. 20233

Assessment and Information Services Center

December 22, 1986 E/AI32:MJD

Dear Colleague:

The Marine Environmental Assessment Division of NOAA's Assessment and Information Services Center (AISC) produces periodic assessments of environmental impacts on economic sectors of marine-related activities. The Chesapeake Bay region served as the first area for AISC assessment development since 1981, and this service is being extended to cover other marine areas. The AISC has also produced marine assessments for the Gulf of Mexico and Puget Sound.

We are pleased to send you the enclosed complimentary copy of the first assessment for the San Francisco Bay area. The assessment is an annual summary for 1985 which includes information on weather, oceanography, fisheries, recreation, transportation, and pollution. The report focuses on the effects of environmental events (weather, oceanography) on economic sectors of marine environmental activity, providing a multidisciplinary view of San Francisco Bay and its use. The nine sections of the assessment emphasize environmental and economic features unique to the San Francisco Bay area. The report also includes a special section on research projects conducted around the Bay in 1985.

Many diverse groups and individuals contributed to the assessment in its preparation and review and we are providing copies to those persons on an exchange basis. The assessment will also be available each year at $5.00 per issue and information on how to subscribe to future issues is enclosed in this package.

Please send any comments or suggestions on the assessment directly to the Project Manager for the San Francisco Bay Assessment, Michael J. Dowgiallo, at the following address: NOAA/NESDIS/AISC, Universal Building, 1825 Connecticut Avenue, N.W., Room 520, Washington, D.C. 20235, telephone (202) 673-5400.

Sincerely yours,

Robert E. Dennis

Robert E. Dennis
Chief, Marine Assessment Branch

Enclosures

A subscription to receive the publication,

"MARINE ENVIRONMENTAL ASSESSMENT, SAN FRANCISCO BAY"

is available for $5.00 per year.

Please make check payable to: "Commerce, NOAA".
Attach check and any request for additional information to this form and mail to:

NOAA/NESDIS/AISC (E/AI11)
Operations Systems and Services Division
Universal Building - Room 524
1825 Connecticut Avenue, N.W.
Washington, D.C. 20235
(202) 673-5407.

NAME: ____________________

ADDRESS: ____________________

____

CITY: ____________________

STATE: ____________ ZIP CODE ____________

TELEPHONE: ____________

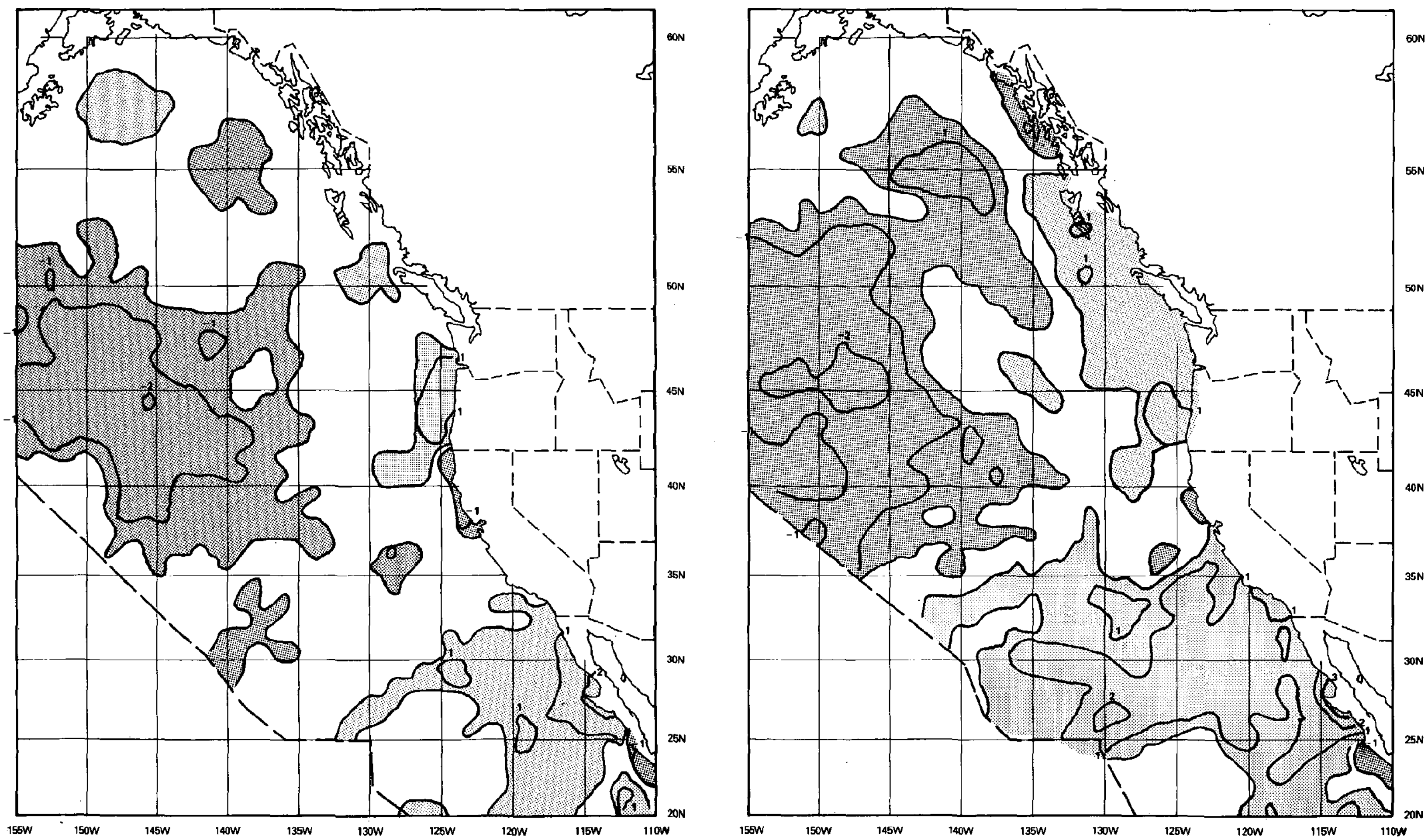


Figure 4.5c Monthly sea surface temperature anomaly. Contour interval ± 0.5°C. Light stippling - positive anomaly; dark stippling - negative anomaly. May, June 1985.

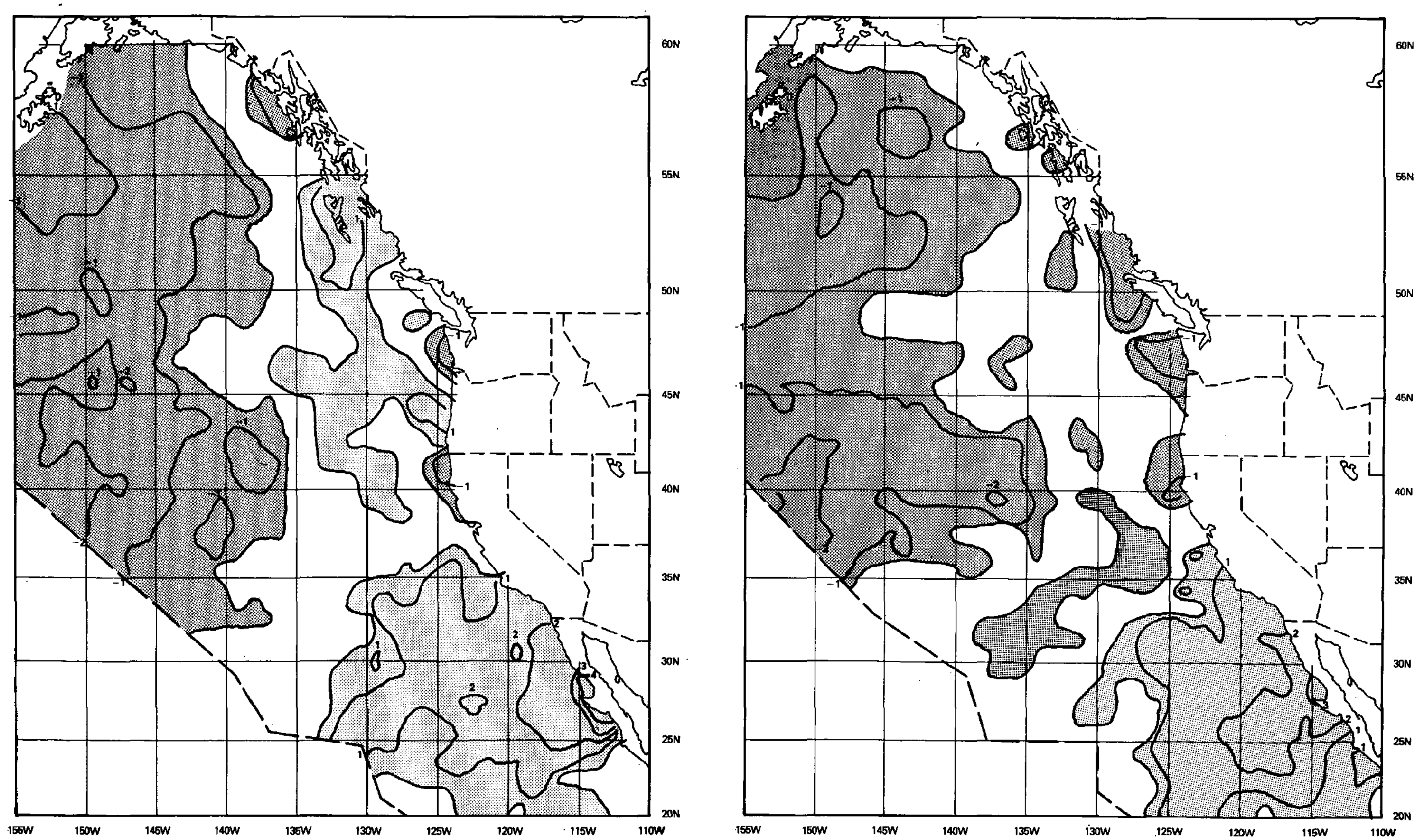


Figure 4.5d Monthly sea surface temperature anomaly. Contour interval ± 0.5°C. Light stippling - positive anomaly; dark stippling - negative anomaly. July, August 1985.

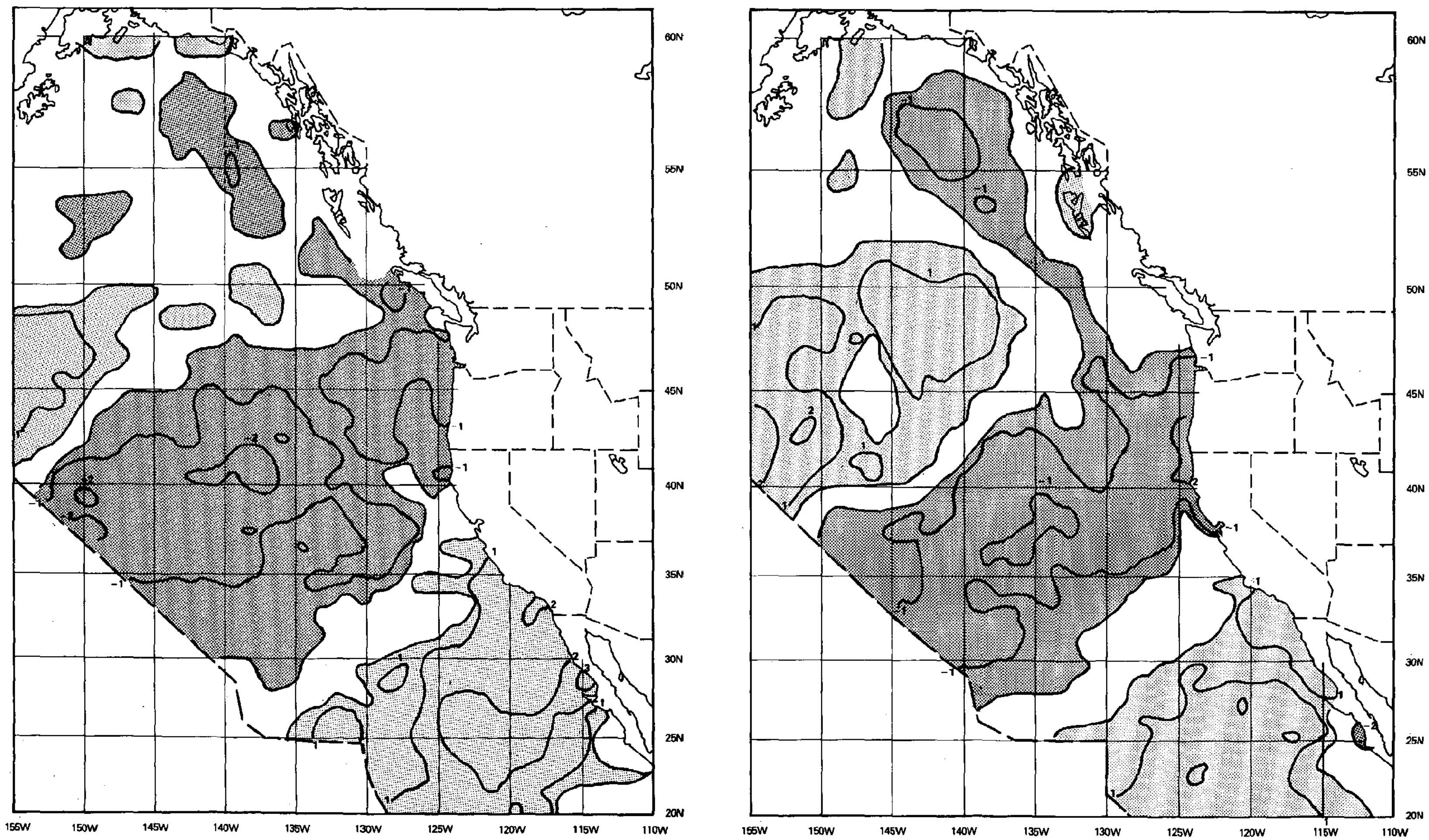


Figure 4.5e Monthly sea surface temperature anomaly. Contour interval $\pm$ 0.5°C. Light stippling - positive anomaly; dark stippling - negative anomaly. September, October 1985.

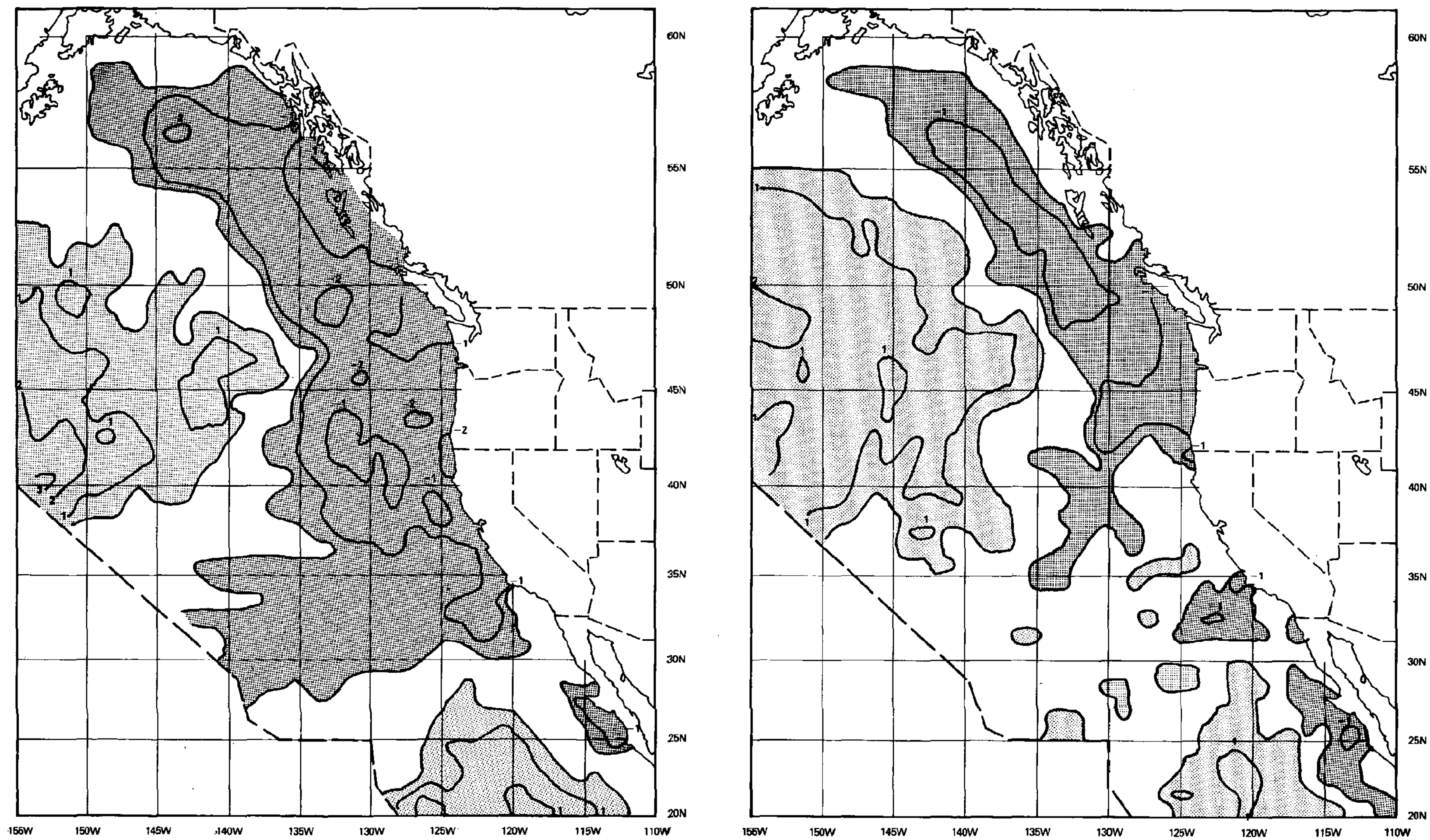


Figure 4.5f Monthly sea surface temperature anomaly. Contour interval ± 0.5°C. Light stippling - positive anomaly; dark stippling - negative anomaly. November, December 1985.

Warmer temperatures to the north of 45°N latitude continued to be observed in February, while south of that latitude more normal conditions prevailed. The strong anticylconic wind-induced flow in the Gulf of Alaska predicted for February probably continued the flow or relatively warm North Pacific waters into the Gulf for the second consecutive month. Cooler-than-normal temperatures were observed along the near coastal grid squares along northern Oregon and Washington State and off Cape Mendocino. Upwelling, wind-induced flows for the Cape Mendocino area could be responsible for the observed cooler temperatures. The waters off Washington and Oregon States are generally advected from the southwest towards the coast, while in February 1985 wind-induced flow was from the northwest. Isolated pools of warmer and cooler waters were observed for the southern portion of the study area. The exception was one large tongue of warmer water which was connected to the Gulf of Alaska warmer waters. South of San Francisco to northern Baja California the coastal squares were mostly above-normal.

The region north of 45°N latitude continued to be warmer-than-normal in March possibly due to the continued strong anticylconic flow about the North Pacific Subtropical High. South of that parallel there were various pools of warmer and cooler waters, while approximately half the area continued to remain at normal (mean) temperatures. Depressed surface temperatures along the coast were limited to south of the Columbia River, Cape Mendocino, Point Reyes, and off Point Eugenia and the tip of Baja California. A large area of cooler waters was centered around 30°N latitude and 132°W longitude. Warmer waters were evident in the Southern California Bight area.

The substantial area of elevated temperatures north of 45°N was reduced in April 1985. The wind-induced transports within the Gulf of Alaska appear to be returning to normal (mean conditions) in March. Coastal waters were mostly near normal. Cooler waters in several pools covered the extreme western portions of the study area. Cooler coastal waters to the north of Point Reyes were observed this month, while warmer coastal waters were seen in the Southern California Bight and at the southern limits of the study area. It appears that the entire region was mostly at near normal temperatures.

The Gulf of Alaska warm waters continued to contract in areal extent in May, while the western cooler waters expanded to the north, south, and east. Cooler coastal waters were limited to the Oregon/California border to San Francisco Bay and the tip of Baja California. Warmer coastal waters were located in the Southern California Bight to southern Baja and the Columbia River south to the cool waters of northern California. It still appears that normal temperatures prevailed over at least half of the study area.

Cooler waters dominated the region west of 135°W longitude while warmer waters controlled the region to the east in June 1985. Coastal cool pools were at two locations, first south of Cape Mendocino to Point Reyes and second at the tip of Baja California. Temperatures to 3°C above normal were located around the area of Point Eugenia (normally an upwelling region).

July 1985 had cooler waters west of 135°W longitude, while warmer waters were to the east of that longitude. Cooler waters along the coast were limited to Washington State and from the Oregon/California border to Point Reyes. Baja California waters showed significant warming this month with coastal and off-shore temperatures warmer by 2-4°C.

The cooling of surface waters dominated the August anomaly chart northwest of a diagonal heading southwest from San Francisco Bay. Warmer waters controlled the California and Baja waters south of San Francisco with temperatures 1°C warmer-than-normal and upwards of 4°C in Santa Rosalia Bay. Cool coastal temperatures prevailed from the Queen Charlotte Islands to south of Cape Mendocino.

The cool waters in the Gulf of Alaska contracted in size in September and near-normal temperatures prevailed over large areas of the Gulf. A tongue of warmer waters entered the study area from the west along the 45° to 49°N latitude line. The diagonal line seen in August heading southwest out of San Francisco Bay continued to delimit the southern extreme of the cool waters and the northern extreme of warmer waters. Cooler waters north of the line replaced the near-normal temperatures of the previous month. Thus cool waters were seen along the coast and to the west from Vancouver Island to Cape Mendocino. The region of warmer waters along Baja California slightly contracted northward while temperatures remained 1° to 3°C above normal.

The warm anomaly along the western boundary of the study area expanded in October north and south, but contracted westward at the expense of the near-normal temperature waters in the Gulf of Alaska and the cooler waters to the south. The southwest tending line out of San Francisco was still apparent this month and still delimited the north-south limits of the warmer/cooler waters. Waters 2°C below normal were observed from Cape Mendocino to north of Cape Blanco, while cooler waters prevailed from San Francisco to the Columbia River. A filament of cooler waters extended northward into the Gulf of Alaska connecting the pool of cooler waters in the Gulf seen in September to the main body of cool waters in the south. Elevated temperatures south of San Francisco prevailed along a southwest tending line off Point Conception. The temperature range was 2°C above normal not the 3° or 4°C seen in the previous months. The near shore and coastal grid squares south of Point Eugenia in Baja California were near normal, while two coastal squares were 2°C below normal.

Cooler surface temperatures dominated in November 1985. The diagonal demarkation line off San Francisco or Point Conception was not apparent this month. Coastal and offshore waters from 34° to 59°N latitude were cooler than normal. The Southern California Bight was at near-normal temperatures as was northern Baja California. Santa Rosalia Bay southward to 25°N latitude had 1°C below normal temperatures. Warmer waters were limited to the western offshore waters off Baja California and from 40° to 53°N latitude and west of 132°W longitude.

Extensive warming occurred in December. The area of warmer temperatures west of 135°W longitude expanded in size, while the large area of cooling off the coast decreased in size. Isolated pools of warmer waters were observed in the southern portion of the study region. Cooler waters were observed from the northern Gulf of Alaska to north of Cape Mendocino. Greater than -1°C anomalies were observed for the coastal and offshore waters of Oregon and Washington States and southern Vancouver Island. Near-normal coastal temperatures were observed from north of Cape Mendocino to north of Point Conception. Point Conception was 1°C and more cooler than normal, while the waters of the Southern California Bight were primarily normal. Central and southern Baja California were slightly below normal with a small 2 or 3 grid square area of -1°C anomaly. The offshore waters of Baja California had slightly elevated temperatures compared to the mean.

4.5 Bay Tides

Water levels in San Francisco Bay have an important impact on shoreline erosion, storm drainage, salinity intrusion, and may affect low-lying marsh land, recreational park land, marinas, and waterside businesses.

Tides in a coastal estuary such as San Francisco Bay are of several types. There is the astronomical tide, due primarily to the moon's motion, the wind tide, most noticeable during storms, and the water level changes due to variable river flow. In addition, there are other sea level changes due to atmospheric pressure differences, coastal waves, tsunamis, and resonent oscillations. The astronomical tide is the most unrelenting source of the Bay's mixing energy.

The astronomical tides in San Francisco Bay are classified as mixed (containing both diurnal and semidiurnal components), but having a strong diurnal variation. Typical tide ranges at the entrance are about 5.5 feet. The geography of the Bay causes the progression of tidal phases in the south bay to differ from that in the north bay. In the southern portion of San Francisco Bay the tide has the character of a standing wave, so that high, or low, water occurs at all shore locations at approximately 1 hour after high water at the mouth. By contrast, the tides in the northern portion of the Bay have a form between that of a progressive wave and a standing wave, with high water at Pt. San Pedro following the high at the Presidio by 1.0 hour, at Mare Island in Carquinez Strait by 1.6 hours, and at Point Buckler in Suisun Bay by 2.7 hours.

During periods of high storm activity and runoff, there can be noticeable changes in water levels in the north bay. Delta flow rates in the range of 90,000 to 180,000 cfs, in combination with periods of low atmospheric pressure lasting one to two weeks, are accompanied by water level increases of as much as 1 foot. During 1985, the peak daily mean flow was only 31,000 cfs and there were no sudden increases in water level.

Wind setup and other local non-tidal influences contribute a relatively minor amount to the water level change. The highest tides due to local winds occur in the south Bay during northerly or northwesterly winds, and in the north Bay during southerly winds. Non-local setup throughout the entire San Francisco-San Pablo Bay area is observed during periods of strong southerly winds, indicating the importance of Ekman transport in the surface layer of the adjacent shelf region. Free oscillations in the southern Bay occur at the dominant natural period of 7 hours. Other water level variations are attributable to shelf waves or atmospheric pressure variations (the inverse barometer effect).

Water level data for 1985 are available for three stations in San Francisco Bay: the Presidio, Alemeda, and San Mateo. Water levels at these stations were close to normal, with no occurences of extreme tides.

4.6 Bay Circulation

The bay circulation, especially the residual circulation, has a direct influence on the flushing of pollutants from the cities, industrial sites, and military installations around the shore. Water currents also determine the transport and replenishment of nutrients in the estuary, the suspension and transport of sediment, and the location of biologically productive areas.

As in most U.S. coastal estuaries, the tides have an important influence on the circulation in San Francisco Bay. Flood current speeds of 3.3 knots or more are found at the Golden Gate, with smaller currents throughout the remainder of the Bay. The residual, or time-averaged, circulation in both arms of the Bay is usually directed upbay in the deeper, central channels, and there is a corresponding return flow over the broad, shallow flats along the shore. The residual circulation is relatively similar from year to year, but varies in strength with the neap-spring tidal cycle and over the course of the year in response to freshwater inflows. The magnitude of the tidal component is largest in the months of June and July, and again in December; magnitudes are lowest during Spring (March and April) and Fall (September and October). Mixing in South San Francisco Bay is greatly influenced by the wind, by the residual tidal circulation, and, in the spring, by density-induced upbay flows.

The current regime in the upper reaches of Suisun Bay is heavily influenced by the discharge from the Sacramento-San Joaquin River delta. A null zone, where the river velocity equals the bottom up-estuary density current, is accompanied by small vertical currents, high sediment deposition, a turbidity maximum, and abundant plankton. During 1985, when the river discharge from the Delta was low (Figure 4.3), the null zone would tend to be further upstream than normal, and flushing of Suisun Bay may have been below normal, allowing higher than normal concentrations of algae and pollutants.

The winds also influence the Bay's circulation, although in more subtle ways than the tides. The spring winds in 1985 were markedly stronger than normal (Table 3.3), causing vigorous vertical mixing throughout the estuary. In South San Francisco Bay, more mixing will suppress vertical salinity gradients, thereby hampering algal blooms. Also, in South San Francisco Bay, stronger spring northwesterly winds will tend to overwhelm the tidal residual circulation, so that net outflow there will more likely occur in the deep channels, which is the reverse of the normal flushing direction.

4.7 Wind Induced Ocean Circulation

This section will discuss the regional, northwest Pacific, wind-induced mass transports. These mass transport vectors represent the vertically integrated flow of water being forced by the surface winds over the ocean (Figure 4.6). The interplay of the atmospheric high and low pressure cells which determines these flows requires this regional approach.

The flow of the North Pacific West-Wind Drift waters is in part controlled by these same highs and lows as are the California and Davidson currents and the Gulf of Alaska gyre. Thus, the flow of cool, nutrient-rich, and oxygenated waters from the North Pacific by the California current or the nutrient-poor warm saline waters from Baja California northward up into southern California are in part controlled by these surface winds and reflected in these mass transport vectors.

The locations and intensity of coastal upwelling and downwelling are directly proportional to the magnitude and direction of those vectors very close to shore. Offshore directed vectors along the coast would indicate surface divergence and upwelling of cooler nutrient-rich waters at that location.

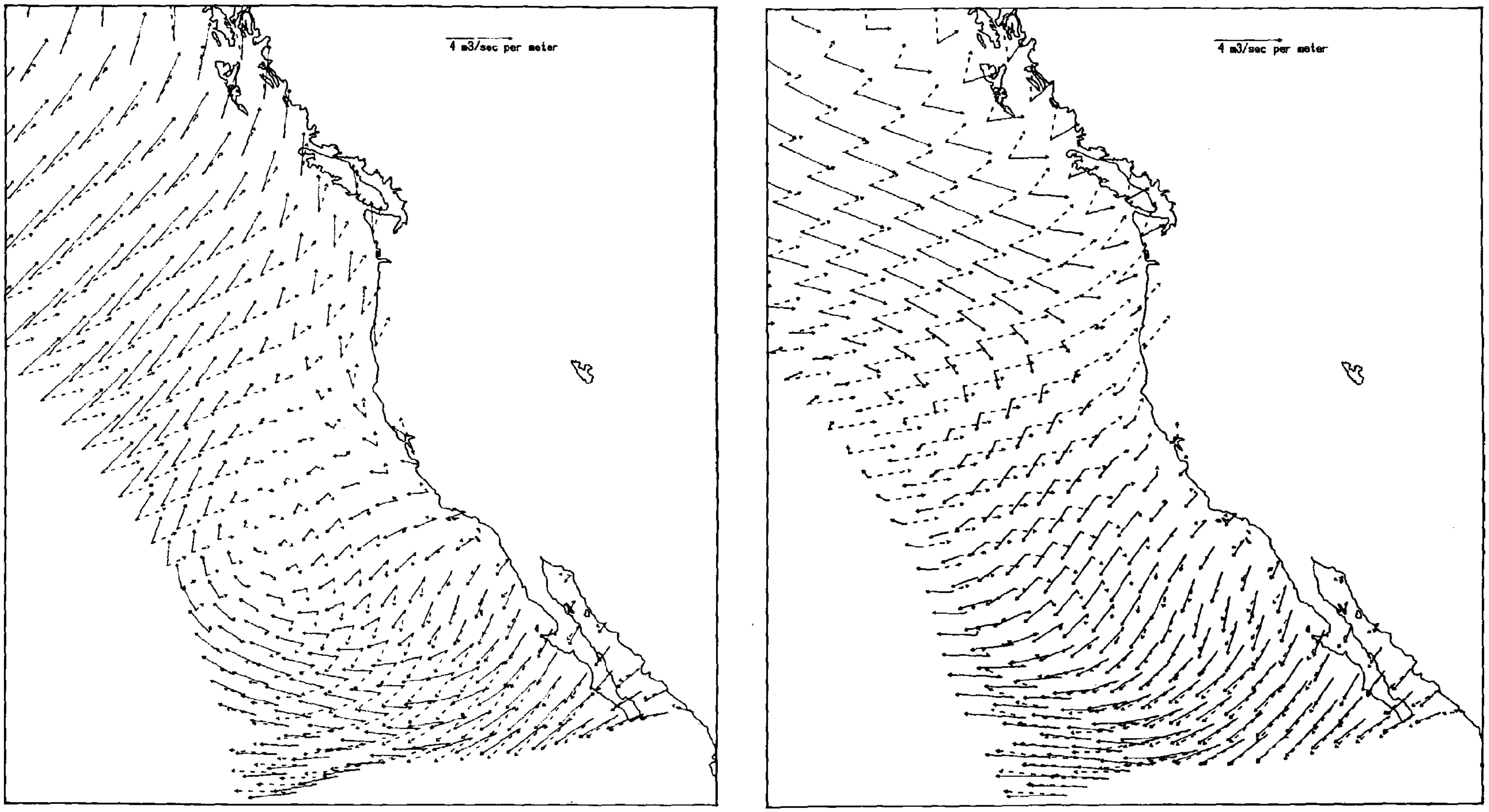


Figure 4.6a Mean monthly wind induced mass transport 1985 and 1978-1984 mean. Solid arrows - 1985; dashed arrows - 1978-1984 mean. January, February.

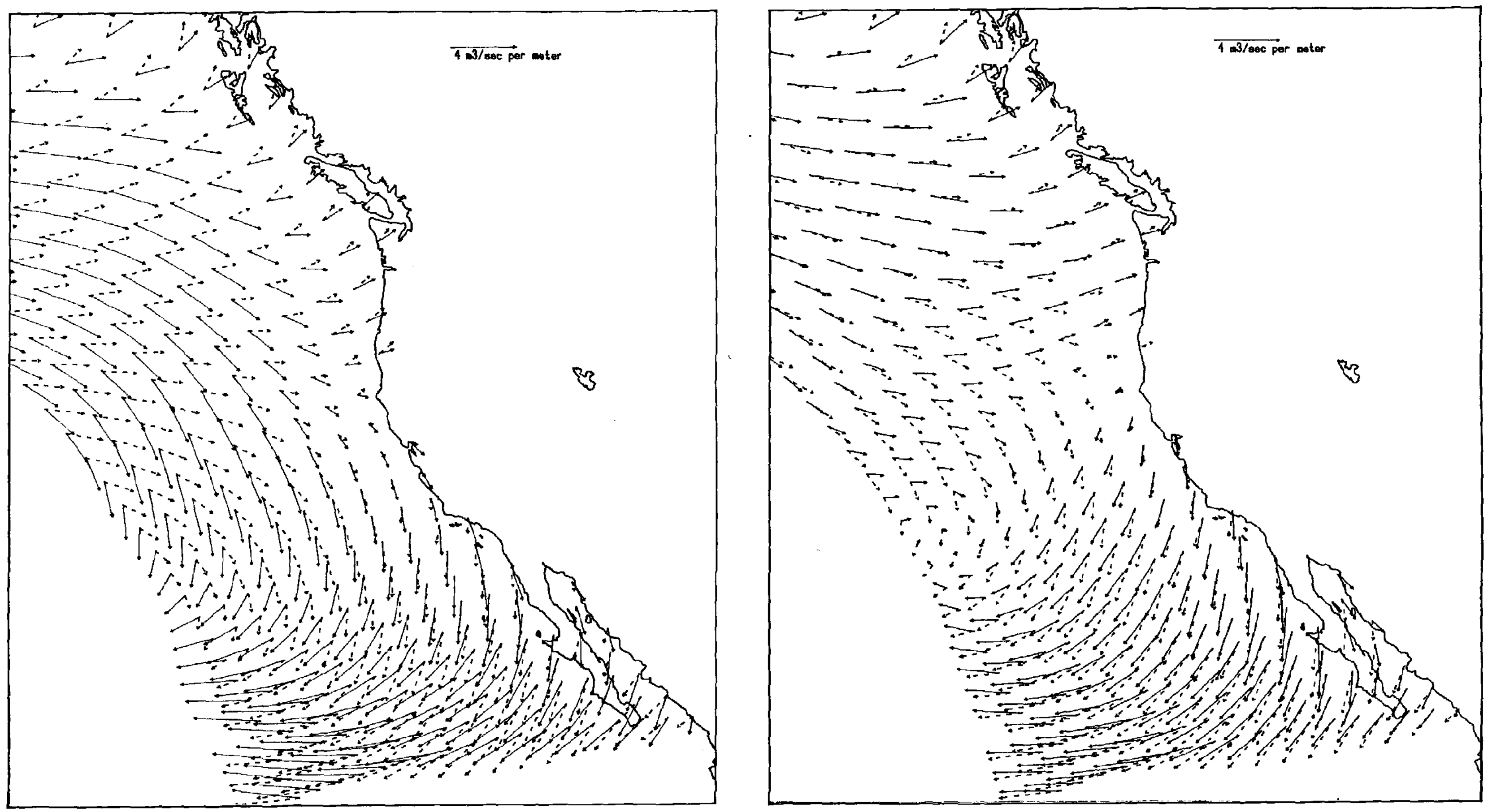


Figure 4.6b Mean monthly wind induced mass transport 1985 and 1978-1984 mean. Solid arrows - 1985; dashed arrows - 1978-1984 mean. March, April.

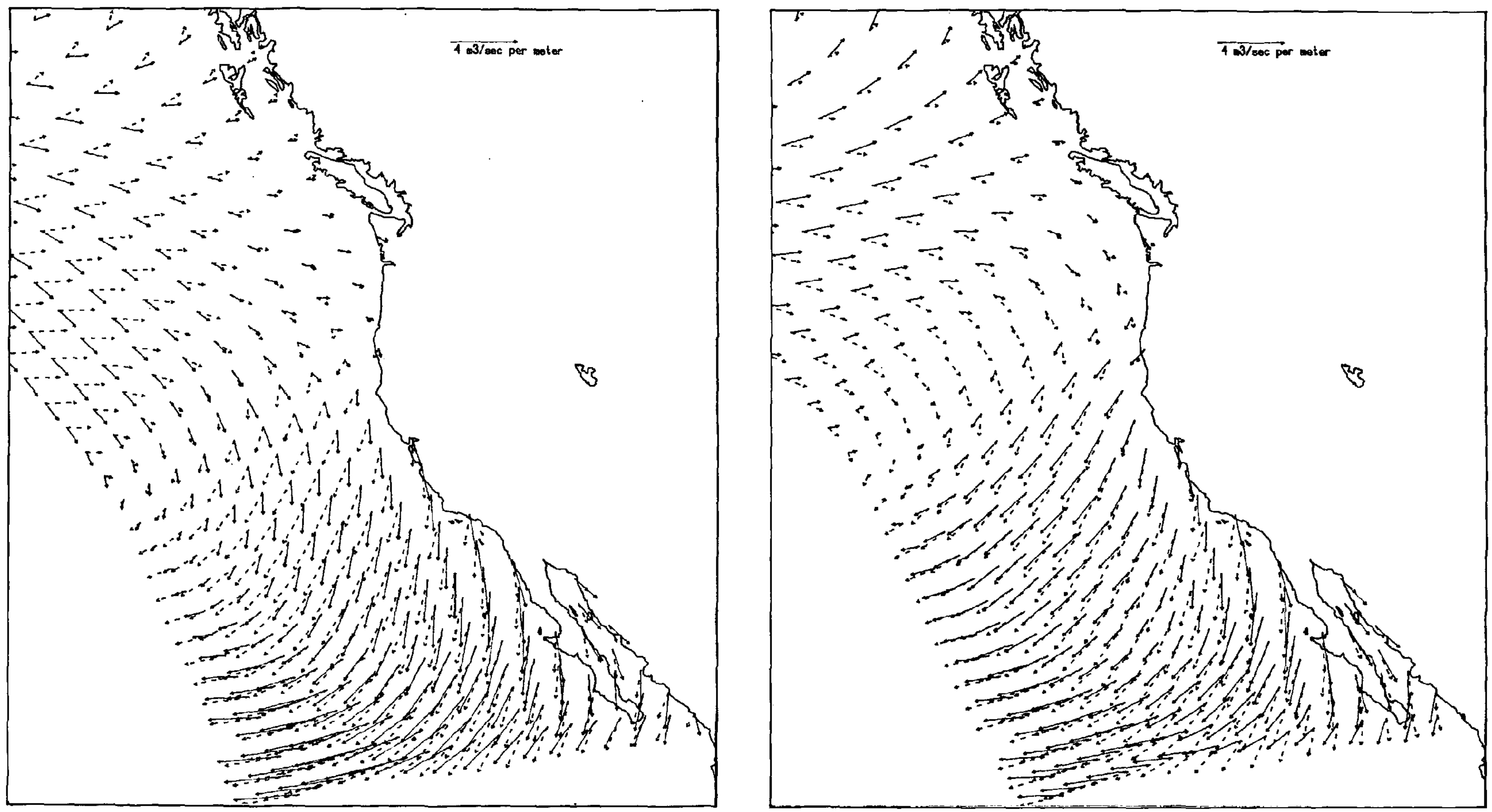


Figure 4.6c Mean monthly wind induced mass transport 1985 and 1978-1984 mean. Solid arrows - 1985; dashed arrows - 1978-1984 mean. May, June.

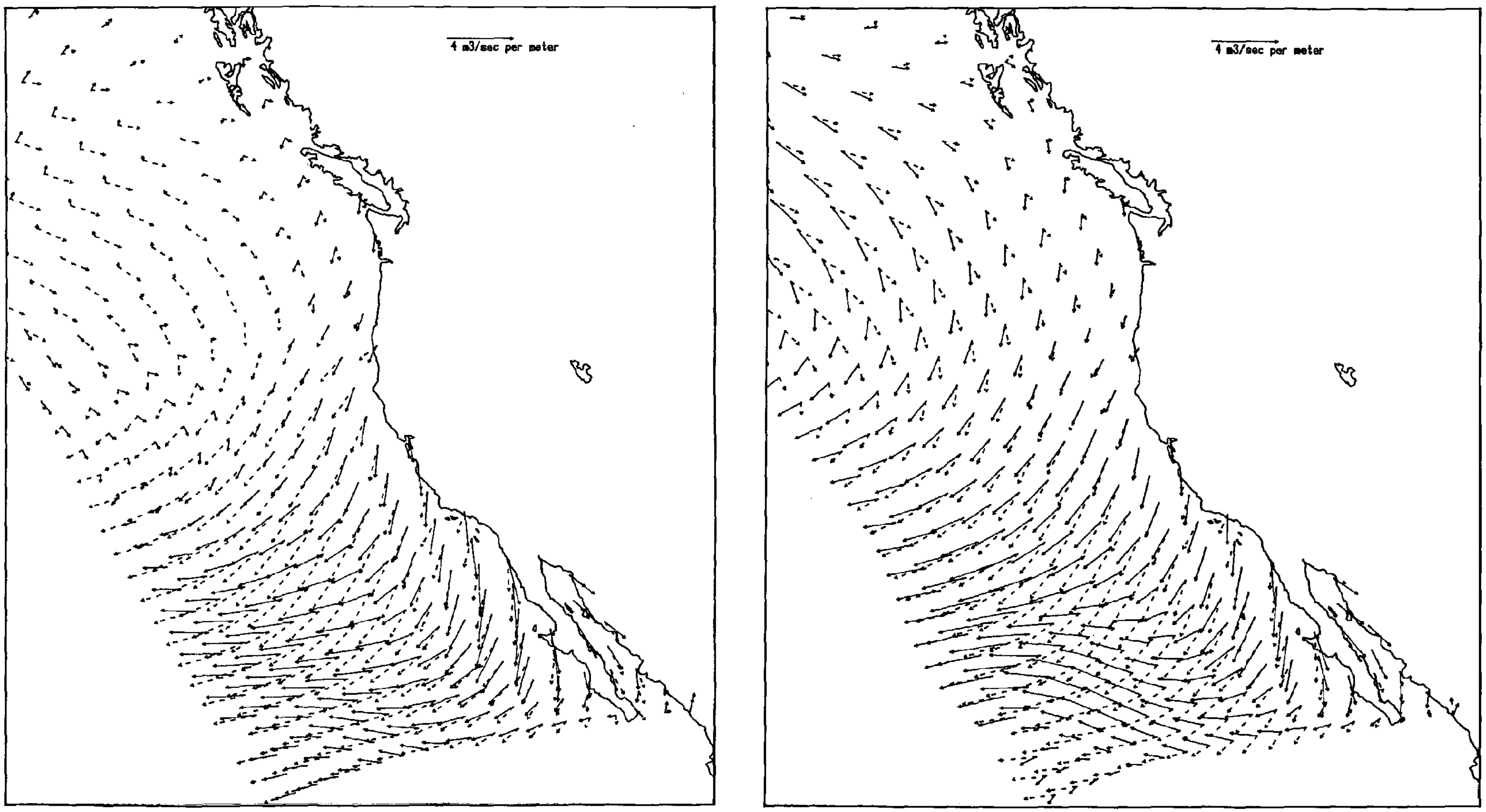


Figure 4.6d Mean monthly wind induced mass transport 1985 and 1978-1984 mean. Solid arrows - 1985; dashed arrows - 1978-1984 mean. July, August.

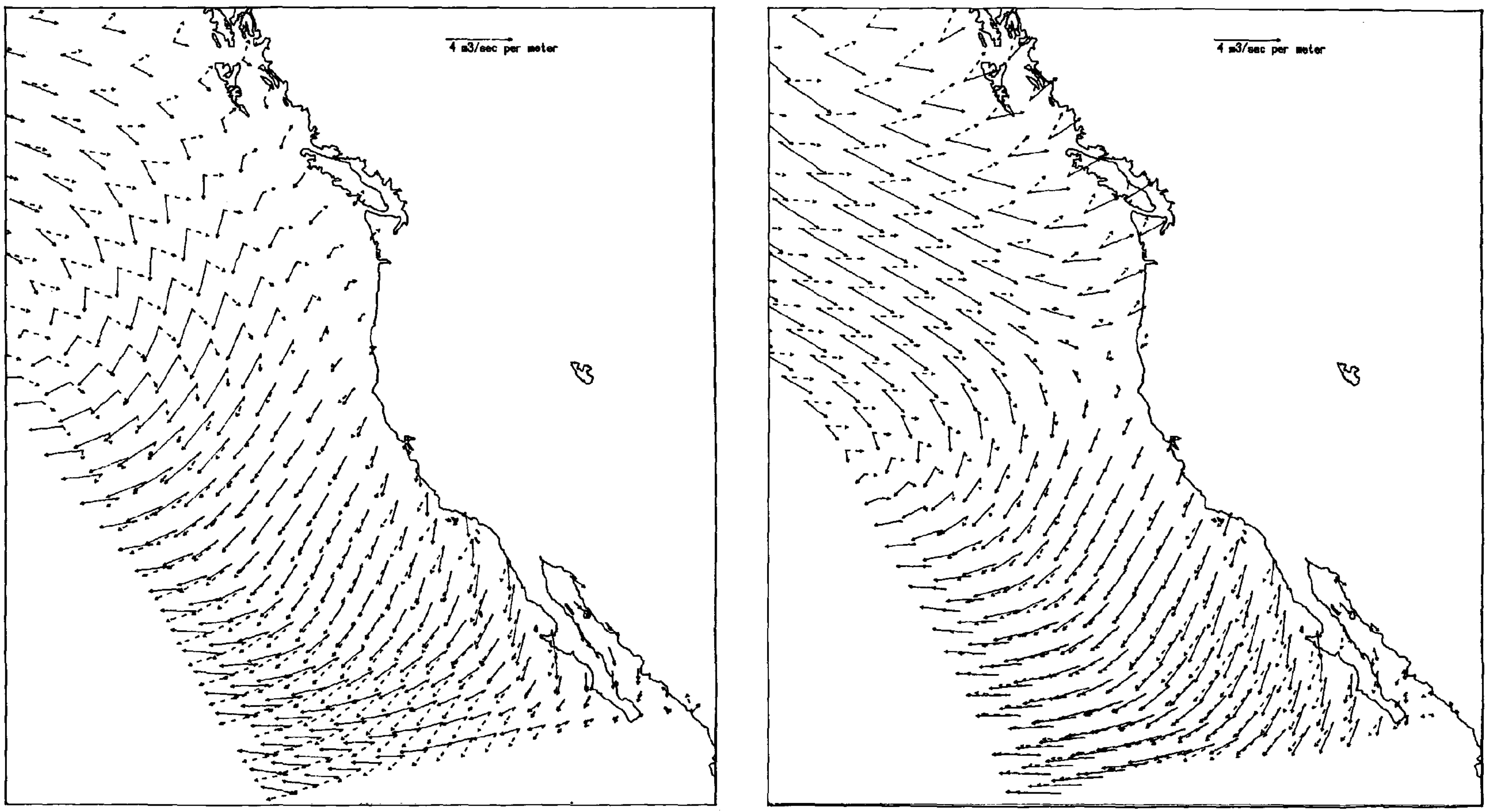


Figure 4.6e Mean monthly wind induced mass transport 1985 and 1978-1984 mean. Solid arrows - 1985; dashed arrows - 1978-1984 mean. September, October.

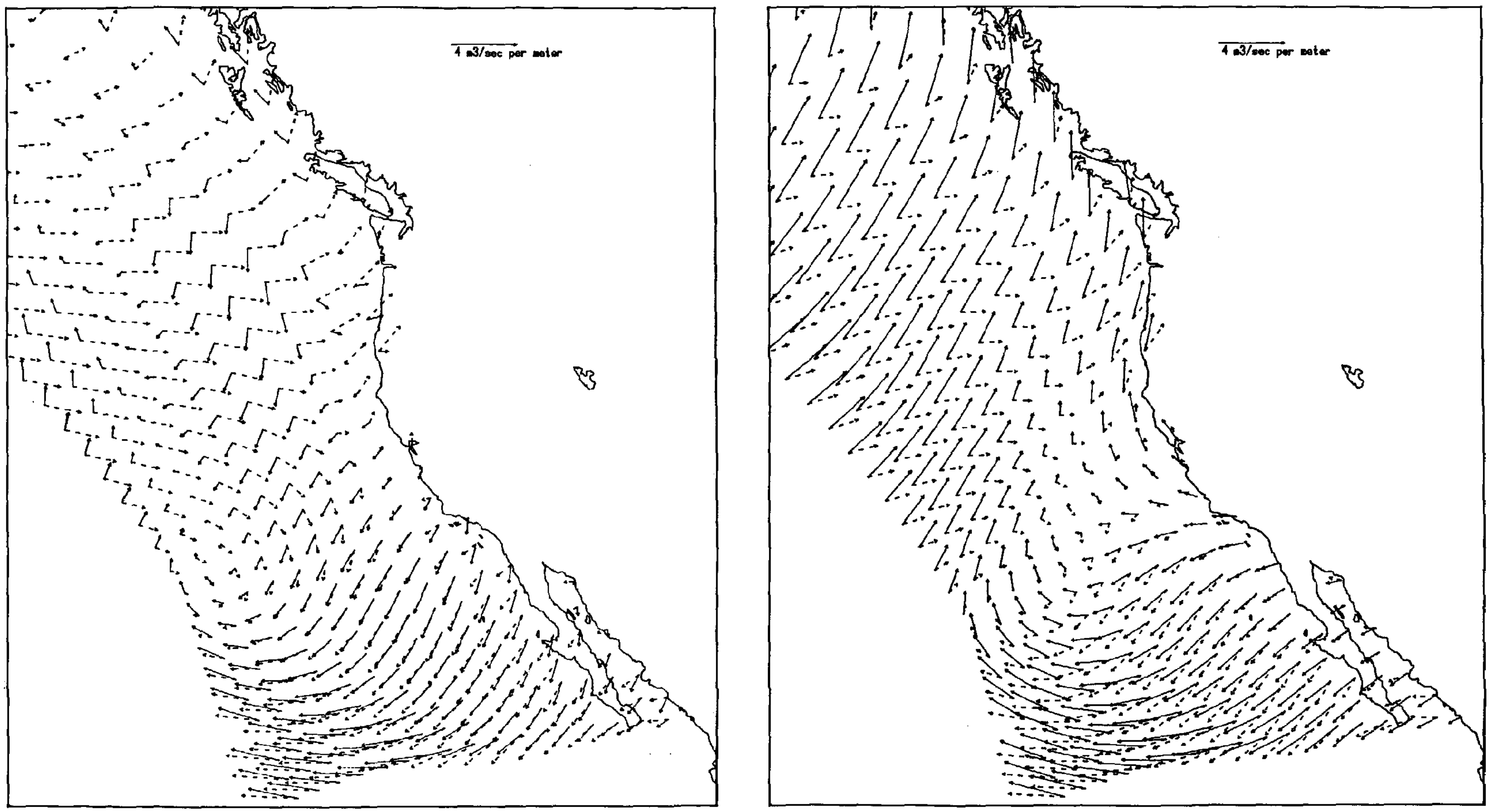


Figure 4.6f Mean monthly wind induced mass transport 1985 and 1978-1984 mean. Solid arrows - 1985; dashed arrows - 1978-1984 mean. November, December.

Onshore flow at the coast indicates downwelling of surface waters at the coast and a build of (increase) of sea level and deepening of the thermocline.

The advection of waters in the major currents of the region and the locations and intensity of upwelling/downwelling areas all have impacts on the regional fisheries. Relating these mass transport vectors directly into fishery impacts isn't performed and probably can not be done at the present level of understanding. It is hoped that the presentation of this type of data and analysis can in time be developed into a fishery indicator.

General Meteorology of the Northwest Pacific

The summer and winter distribution of the high and low pressure cells for the Northwest Pacific will be discussed. Lows with its cyclonic winds will result in counterclockwise directed mass transports while the high pressure cells with it's anticyclonic flow will result in mass transports rotating in a clockwise direction about it's center.

January in figure 4.7 is typical of the winter locations of the North Pacific Subtropical High (NPSH) and the Aleutian Low. These are the generalized locations for the height of winter. There are inter-annual variations in their locations and intensity as well as the seasonal progression event in the monthly mass transport vectors.

The northeast trade winds dominate the area of southern California to beyond Baja California. These trade winds vary in intensity but in general the flow is approximately constant throughout the year.

The summer distribution of highs and lows is depicted in Figure 4.7.1b. Note, that the Aleutian Low is not present while the NPSH has increased in size and intensity and now controls the flows in the Gulf of Alaska vacated by the Aleutian low. A thermal low is produced over the Imperial Valley area of California is summer due to the heating of the surface. This cyclonic flow intensify the downcoast winds for the western U.S. coast resulting in the intense upwelling of Cap Mendocino and upwelling in Oregon and Washington state.

Data Description

Monthly mean wind-induced mass transports for the west coast region of the United States, Canada, and Mexico were generated for 1985. Climatological monthly means were also produced for the period of record from September 1977 through December 31, 1984. These mass transport values were then drawn as vectors over a Mercator projection base map of the study region. A one inch long vector represents a vertically average mass transport of 4 cubic meters per second per meter perpendicular to the direction of flow.

The wind data used in generating the mass transport values were taken from the output generated by the National Weather Service's Limited Area Fine-mesh Model II (LFM). The 6 hour predictions from the 0 and 12 GMT LFM model runs for the lowest 50 millibars of the atmosphere were the wind data utilized.

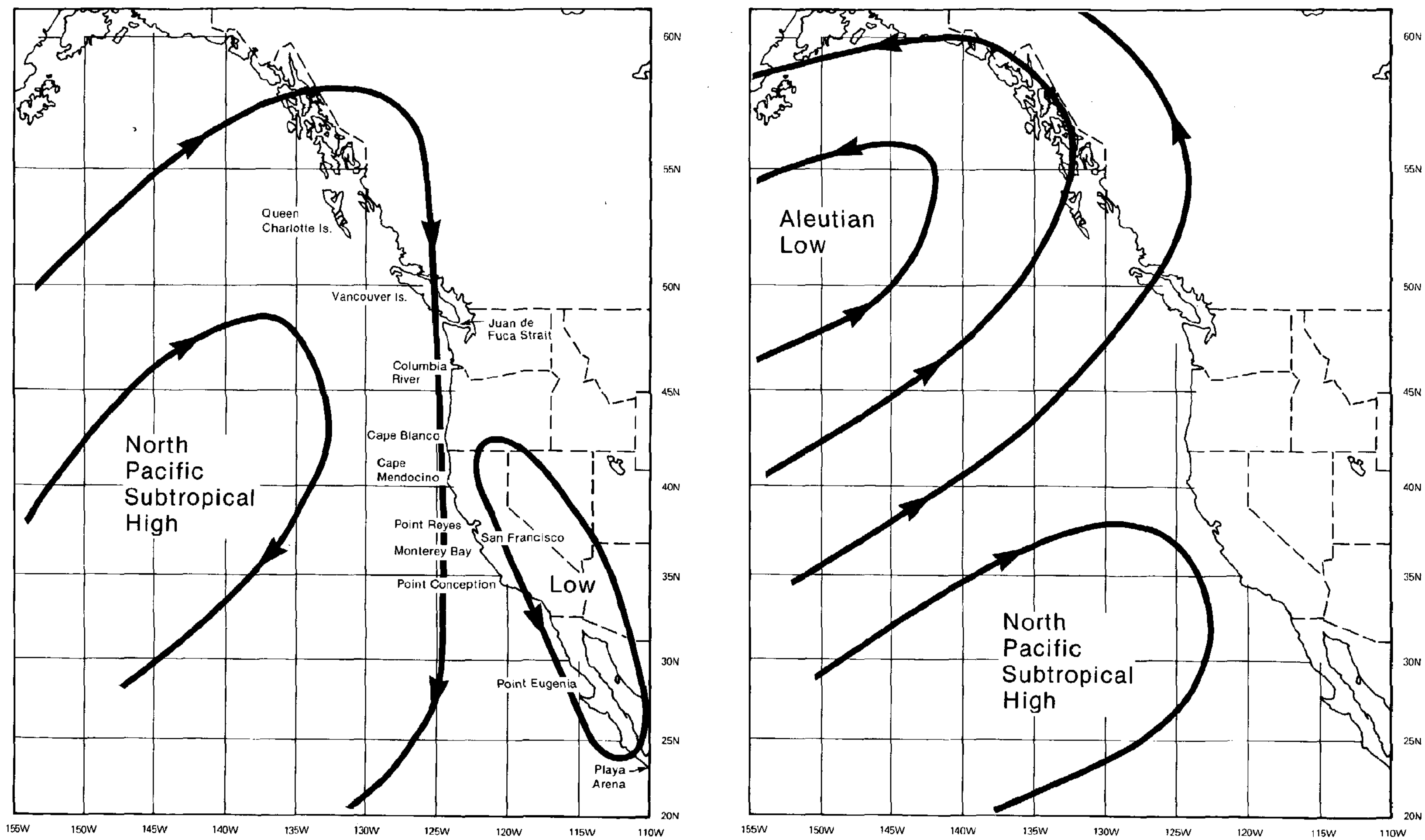


Figure 4.7 Generalized surface wind flow pattern off western U.S. coast in summer (left) and winter (right).

The twice daily wind speed and direction data at these selected LFM offshore sites were then used as input data for a mass transport model developed by Huang. The resultant vertically averaged mass transports are 45° to the right of the wind vector not the 90° predicted by Ekman. When compared to Bakun's techniques the Huang mass transport vectors are of a larger magnitude and rotated 45° less to the right.

Monthly mean values of eastward and northward components are generated by vectorially summing the twice daily calculated mass transport values. The climatological mean (hearafter referred to as the mean) is produced by averaging the monthly mean values for the previous years of data.

Monthly Summary of the Mass Transport Data

A condensed summary of the major features of the wind induced flows for each month of the year follows. A comparison with the 1977-1984 climatological mean flows will also be included.

The counterclockwise wind-induced mass transports for the Gulf of Alaska to northern California were substantially larger in January 1985 than the mean. Thus, increased flow of West-Wind Drift water into the Gulf of Alaska system was possible. Northwestward to northward flow characterized the coastal region from Monterey Bay to Vancouver possibly augmenting the flow of the Davidson Current. Clockwise transports were evident in the remainder of the study region. Upwelling was probable from Point Conception southward.

The NPSH dominated the flow in the Gulf of Alaska and the remainder of the region in February. Strong southward flow from the Gulf of Alaska to the nearshore waters of Washington State to northern California were predicted. Thus, increasing the flow of cool nutrient-rich waters into the California Current system. Upwelling was probable from Point Conception southward while downwelling was probable from north of Cape Blanco.

The NPSH remained in control of the transports for the Gulf of Alaska southward during March 1985. The only difference between the March 1985 data and the mean was in the Gulf of Alaska with the strong southeast flow instead of the mean northeast flow. Coastal areas and southern portion of the study region showed that the mean flows prevailed. Onshore flows for Canada to Cape Mendocino became downcoast flow by Point Arena and then offshore flow in Baja California.

April wind-induced mass transports agreed favorably to the mean. Strong east-southeastward flow from the Gulf of Alaska to the Canadian coast and offshore waters of Washington State characterized the northern portion of the study region. Downwelling flows along the Canadian, Washington, and Oregon coasts became upwelling flows from Point Conception to the tip of Baja California.

The May 1985 flow was comparable to the mean for direction of flow but showed reduced magnitudes of flow for the offshore vectors from the Gulf of Alaska to Point Conception. Thus, a reduced flow of West-Wind Drift waters into the California Current system might be expected for this month. Downwelling continues this month for the Canadian waters to north of Cape Blanco. Downcoast flow from Cape Blanco to Point Eugenia became offshore upwelling flow at the tip of Baja California.

NPSH controls the wind-induced transports for the study region during June 1985 as expected from the climatological means. Coastal upwelling could have be initiated from Cape Blanco southward to the tip of Baja California. Prior to June upwelling was localize to the Point Conception, Point Eugenia, and southern Baja California. The major difference between the 1985 predictions and the mean was the ridge of high pressure that was tending from southwest to northeast off the Juna de Fuca Strait which resulted in a linear convergence zone. Reductions in the magnitudes of the trade wind mass transports were evident in June 1985 and in the means as well.

A low over the western Aleutians resulted in cyclonic flow in the Gulf of Alaska instead of the mean anticyclonic flow in July 1985. This could result in reduced flow of Gulf of Alaska water southward into the California Current system. The remainder of the study region was at near normal direction and magnitudes. Coastal upwelling persists from Cape Blanco south.

August flows compared favorably to the 1977-1984 climatological means. Moderate flow of Gulf of Alaska waters into the California Current system and upwelling form Cape Blanco to Point Conception and the tip of Baja California were predicted.

The NPSH moved northward in September compared to its mean position resulting in offshore flows which intensified westward for the Oregon to northern California area. Reduced flow of gulf of Alaska waters to the California Current system were again predicted this month. Mass transports favorable for upwelling were predicted from Vancouver Island south.

October 1985 saw significant changes in the transport vectors in the northern portion of the study area, while the southern portion generally agreed with the mean. Stronger than normal transport of Gulf of Alaska water southeastward occurred in the northern portion of the study region. Downwelling of coastal waters was predicted from Cape Blanco northward while upwelling was predicted for the coastal region south of Cape Mendocino. Strong trade wind-induced transports were predicted for the first time since June.

A series of two high pressure cells dominated the flows in November 1985. The mass transports were radically different with a linear convergence zone located off the California to Vancouver coasts. Reduced flow of West-Wind Drift and Gulf of Alaska waters into the California Current system would be expected. Upwelling could be expected from Cape Mendocino southward to the offshore directed mass transports.

Stronger than normal cyclonic flows were predicted for the northern portion of the study area in December, while near normal trade wind transports were evident in the south. Increased upcoast flow from Monterey Bay to Juan de Fuca Strait could have resulted in an augmented Davidson Current for that coastal region. The flow of West-Wind Drift waters into the California current system could again be reduced this month while stronger flows into the Gulf of Alaska were predicted. Upwelling was probable from Point Conception to the tip of Baja California, while downwelling is expected for the Canadian waters.

5. FISHERIES AND BIOLOGICAL RESOURCES

5.1 Introduction

The San Francisco Bay estuary presently supports sport fisheries and a limited commercial fishery, and serves as a spawning and nursery ground for ocean species which use the estuary for a portion of their life cycles. The commercial fishery once included many species caught within the bay. Overfishing and habitat degradation have since greatly diminished the commercial harvest to only a few species.

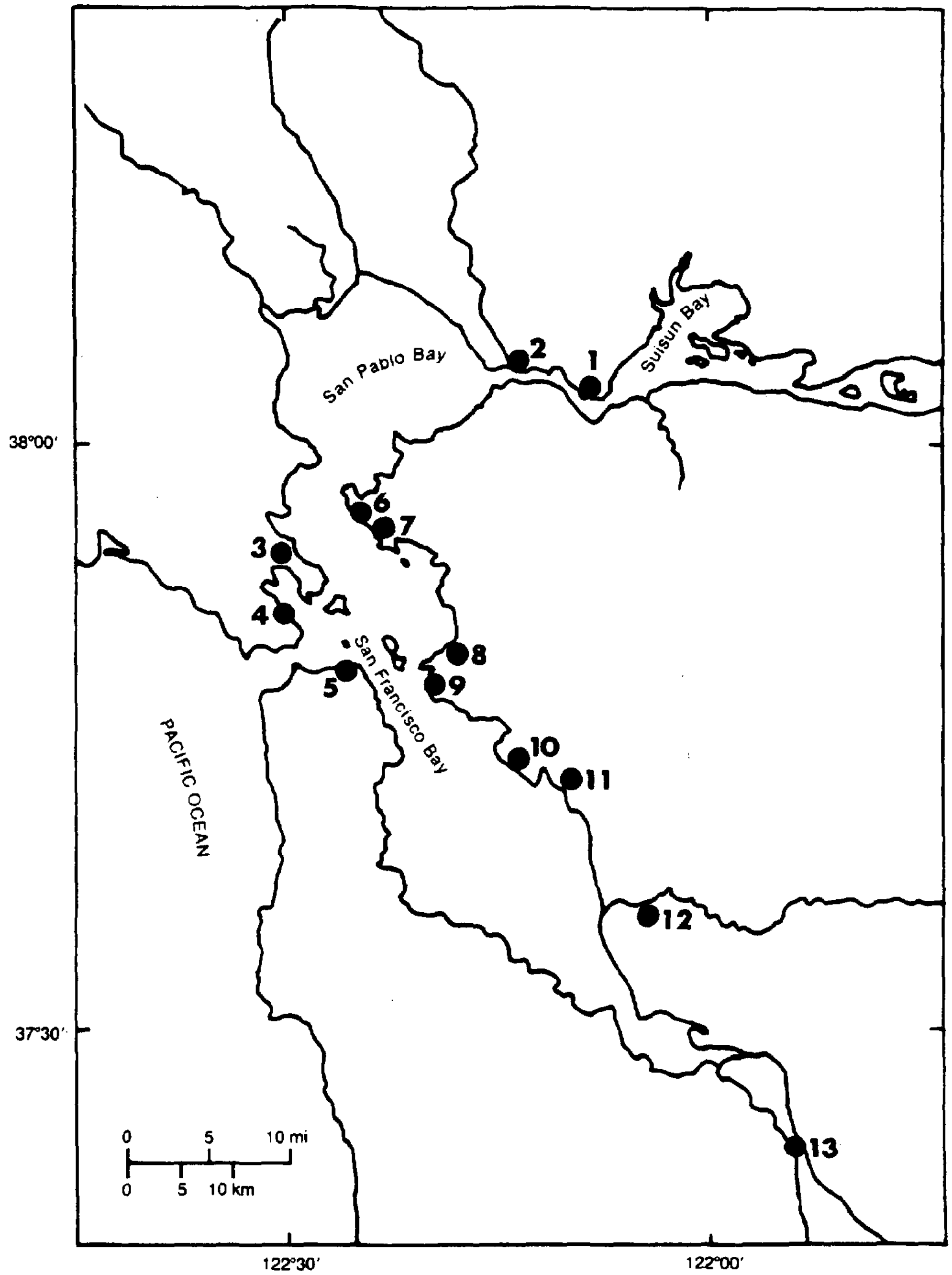
The commercial species actually caught within San Francisco Bay presently include only herring, anchovy, and the grass shrimp, Crangon. Small quantities of surfperch, sharks, salmon, flounders and gobies are also taken commercially within the Bay. However, landings brought into San Francisco area ports from outside the Bay are substantial in both quantity and diversity. Landings data for 1984 and 1985 from the California Department of Fish and Game show that fish and shellfish are landed at 40 to 60 ports in the San Francisco area. Many of these ports handle small quantities and are located north, south, and inland of the Bay. Some of the ports, which are located inland, are primarily processing facilities that handle fish caught offshore in the coastal ocean. Fish and shellfish landed at ports within San Francisco Bay are brought in through the three major ports, San Francisco, Sausalito, and Oakland, and ten other ports which handle smaller quantities (Figure 5.1).

The Bay Area commercial fishing industry has survived over recent years, as availability of certain species and markets have changed. Of the six port areas in the State of California, San Francisco ranked fourth highest in 1985 in landings (Table 5.1.). The San Francisco area and only two other areas, Santa Barbara and Eureka, showed increases in landings from 1984 to 1985.

Table 5.1. Total landings of commercial species at California port areas.

	Landings by year in millions of pounds					
Port area	1940	1954	1965	1975	1984	1985
Eureka	11	27	30	55	50	66
San Francisco	189	20	17	18	38	43
Monterey	370	26	25	38	45	30
Santa Barbara	5	51	22	76	28	50
Los Angeles	522	359	383	602	237	167
San Diego	128	138	65	70	43	6

Data from California Department of Fish and Game. All data before 1985 were extracted from California Department of Fish and Game records by the Bay Conservation and Development Commission.



1. Benicia
2. Vallejo
3. San Rafael
4. Sausalito
5. San Francisco
6. Richmond
7. Berkeley
8. Emeryville
9. Oakland
10. San Leandro
11. Hayward
12. Fremont
13. San Jose

Figure 5.1. Fishing ports of San Francisco Bay.

5.2 Summary of Activities

Forty-three million pounds of finfish and shellfish worth $20.9 million were landed at all ports in the California Department of Fish and Game San Francisco reporting area in 1985. Total landings for this area in 1984 were lower than in 1985, at 38.6 million pounds valued at $16.9 million. Thirty-one million pounds of finfish and shellfish were landed at the ports actually within San Francisco Bay in 1985, worth $12.5 million (Table 5.2). These landings also represent an increase over landings in 1984, though lower in quantity than landings in 1982 and 1983.

Table 5.2 Total poundage and value for finfish and shellfish landed at ports within San Francisco Bay and the State of California for years 1982 through 1985.

	Million pounds			
	1982	1983	1984	1985
San Francisco Bay ports	43.5	42.0	22.4	31.0
State of California	695.4	528.9	459.2	362.8
San Francisco as percent of State total	6.0	8.0	5.0	9.0

	Million dollars			
	1982	1983	1984	1985
San Francisco Bay ports	18.3	22.2	9.2	12.5
State of California	241.2	202.1	176.6	132.9
San Francisco as percent of State total	8.0	11.0	5.0	9.0

Preliminary data from National Marine Fisheries Service.

5.3 Finfish

Five categories of finfish dominated the landings into San Francisco area ports in 1985: Pacific herring, rockfish (Scorpaenidae), sole, sablefish, and chinook salmon Landings of Pacific herring were highest in quantity and value, at 17.3 million pounds worth $5.9 million. The combined totals for finfish landed in 1985 represent over 100 species with a total quantity of 42.2 million pounds worth $19.2 million. The total quantity of fish landed was an increase from the 37.6 million pounds of fish landed in 1984. While some species such

Table 5.3. Commercial finfish landings into the San Francisco Bay area, 1984-85.

Species	1984 Pounds	1984 Dollars	1985 Pounds	1985 Dollars
Anchovy, northern	1,185,437	137,437	570,411	65,290
Bonito, Pacific	1,024	227	-	-
Butterfish, Pacific	949	813	2,438	1,488
Cabezon	11,954	2,636	7,845	1,320
Croaker, white	426,301	127,548	443,022	151,608
Fish, unspecified	53,047	23,605	7,712	3,745
Flounder, arrowtooth	3,885	1,149	6,362	2,137
Flounder, starry	337,154	104,346	241,164	82,682
Flounder, unspecified	31,069	10,647	103,376	34,966
Hake, Pacific	5,423	465	5,510	620
Halibut, California	305,405	451,163	236,077	386,996
Herring, Pacific	8,125,448	1,852,197	17,276,840	5,914,613
Jacksmelt	1,869	548	12,083	1,448
Lingcod	1,234,084	314,245	720,917	203,741
Louvar	1,023	816	-	-
Mackerel, unspecified	35,616	5,595	32,709	6,776
Opah	13,154	3,133	4,992	1,324
Rockfish, all species	14,255,075	3,551,007	10,528,265	3,018,348
Sablefish	1,529,628	249,408	2,573,653	745,324
Salmon, unspecified	20,451	57,460	11,188	31,417
Salmon, chinook	1,476,802	4,108,280	2,128,492	5,512,664
Salmon, coho or pink	183,105	376,148	13,859	22,205
Sanddab	203,403	72,750	320,179	115,954
Shark, all species	233,455	149,955	259,477	193,159
Skate, unspecified	52,591	13,303	54,148	13,604
Smelt, surf	7,754	2,873	3,009	1,268
Smelt, true	4,537	1,206	9,082	2,842
Smelt, whitebait	14,213	5,065	21,968	7,984
Sole, all species	5,297,526	1,548,061	5,166,707	1,621,658
Surfperch, unspecified	42,943	52,074	34,322	39,929
Swordfish	381,898	873,446	186,742	436,775
Thornyhead	531,840	128,611	462,524	116,311
Tuna, albacore	1,619,170	869,512	890,488	444,736
Tuna, yellowfin	-	-	1,243	1,036
Turbot	3,125	739	5,472	1,285
Unknown	9,447	2,102	13,413	12,718
Yellowtail	32,281	6,667	27,157	8,974
Totals	37,675,950	15,114,886	42,152,733	19,209,520

Data from California Department of Fish and Game. Landings for species of less than 1,000 pounds reported are not listed individually. Blank indicates data not available or none reported. Figures for 1985 are preliminary.

as northern anchovy and albacore tuna showed declines, Pacific herring landings showed a very large increase of over twice the 8.1 million pounds landed in 1984.

West Coast fisheries were affected by unusually warm sea surface temperatures associated with the El Nino - Southern Oscillation (ENSO) event in 1983. Altered fish distributions and reduced growth rates were seen in important commercial species such as salmon and herring during the period of warm water temperatures and reduced upwelling in 1983. Water temperatures along the West Coast have shown an above-normal annual trend since 1977. Water temperatures at Fort Point, California (near the Golden Gate), are listed in Table 5.4.

Table 5.4. Average monthly water temperatures (Deg. F) for Fort Point, California, 1983-85, with 10 and 30 year monthly averages.

Month	Year 1983	Year 1984	Year 1985	1976-85 Average	1955-84 Average
January	50.7	54.1	51.9	52.0	50.9
February	54.3	55.5	53.9	53.7	52.2
March	55.5	56.4	53.3	54.6	51.8
April	56.0	56.4	55.3	55.0	54.8
May	54.6	56.8	55.4	55.4	54.9
June	57.9	58.5	58.2	57.4	56.9
July	58.8	61.8	60.1	59.1	58.1
August	62.6	61.6	61.4	60.8	59.7
September	64.3	63.3	60.6	61.2	60.2
October	63.9	60.8	58.9	59.8	58.9
November	61.1	56.3	53.8	56.8	55.6
December	55.3	53.9	50.1	53.3	52.3
Annual average	57.9	58.0	56.1	56.1	55.5

Data from NOAA, National Ocean Service.

Biological responses to the warm water temperatures were evident in redistributions of fish species, particularly warm water species which moved northward along the West Coast during the ENSO event. In 1983, the California Department of Fish and Game recorded 30 warm-water finfish species along coastal California. These species, such as the blenny, Hipsoblennius, are not typically found in the colder areas of the coast where they were reported in 1983. However, warm-water species were also reported in 1984 and 1985 in areas where they are not typically found, coinciding with the warmer-than-normal water temperatures observed along the California coast in 1984 and 1985.

Herring constitute an important commercial fishery within San Francisco Bay. Herring are harvested only in December through mid-March coinciding with their spawning season in San Francisco Bay, which begins in late October and ends in March. Herring are caught primarily for the value of their eggs, or roe, which are used entirely for export purposes. Landings include the total weight of all fish caught (males and females) including roe. Average dockside price is approximately $1,000 per ton. The December fishery is limited to gill netters in the "XH" (experimental herring) platoon. "XH" permittees are only allowed to fish in December and only if the spawning biomass from the previous season was at least 36,000 tons from January to March, or until the quotas are r ached. Herring are harvested by two other platoons of gill netters ("odd" and "even"), purse seiners, and lampara net vessels. Each group has a quota. During the last ten years, season quotas have ranged from 4,000 to 10,000 tons and are set by the California Department of Fish and Game. Quotas are based on the sum of the commercial catch plus spawn escapement, based on egg deposition surveys from the previous season and generally do not exceed 20% of the total spawning biomass.

The highest quotas during the last ten years were for the 1981-82, 1982-83, and 1983-84 seasons, set at 10,000, 10,399 and 10,399 tons, respectively. (Figure 5.2). The actual catch during the 1983-84 season was only 2,838 tons, as herring stocks were greatly reduced in the Bay area during the period of anomalously-warm-sea-surface temperatures in 1983. Adult herring schools showed reduced growth rates in the 1983-84 season. The herring harvest showed recovery in the 1984-85 and 1985-86 seasons, though the landings were below landings in the 1981-82 and 1982-83 seasons which preceded the precipitous drop in catch following the ENSO event.

Table 5.5 lists herring caught within San Francisco Bay by gear type for the 1983-84, 1984-85, and 1985-86 seasons.

Table 5.5. Commercial landings of herring for San Francisco Bay by gear type, spawning seasons 1983-84, 1984-85, and 1985-86.

	Tons		
Gear type	1983-84	1984-85	1985-86
Gill net (XH)	47	1,418	1,589
Gill net (odd)	516	1,822	2,226
Gill net (even)	966	2,266	1,790
Purse seine	892	1,128	881
Lampara	407	1,106	792
Totals	2,828	7,740	7,298

Data are preliminary from California Department of Fish and Game.

Anchovy landings of 0.6 million pounds in 1985 were considerably lower than the 1.2 million pounds landed in 1984 (Table 5.3). Anchovy move in and

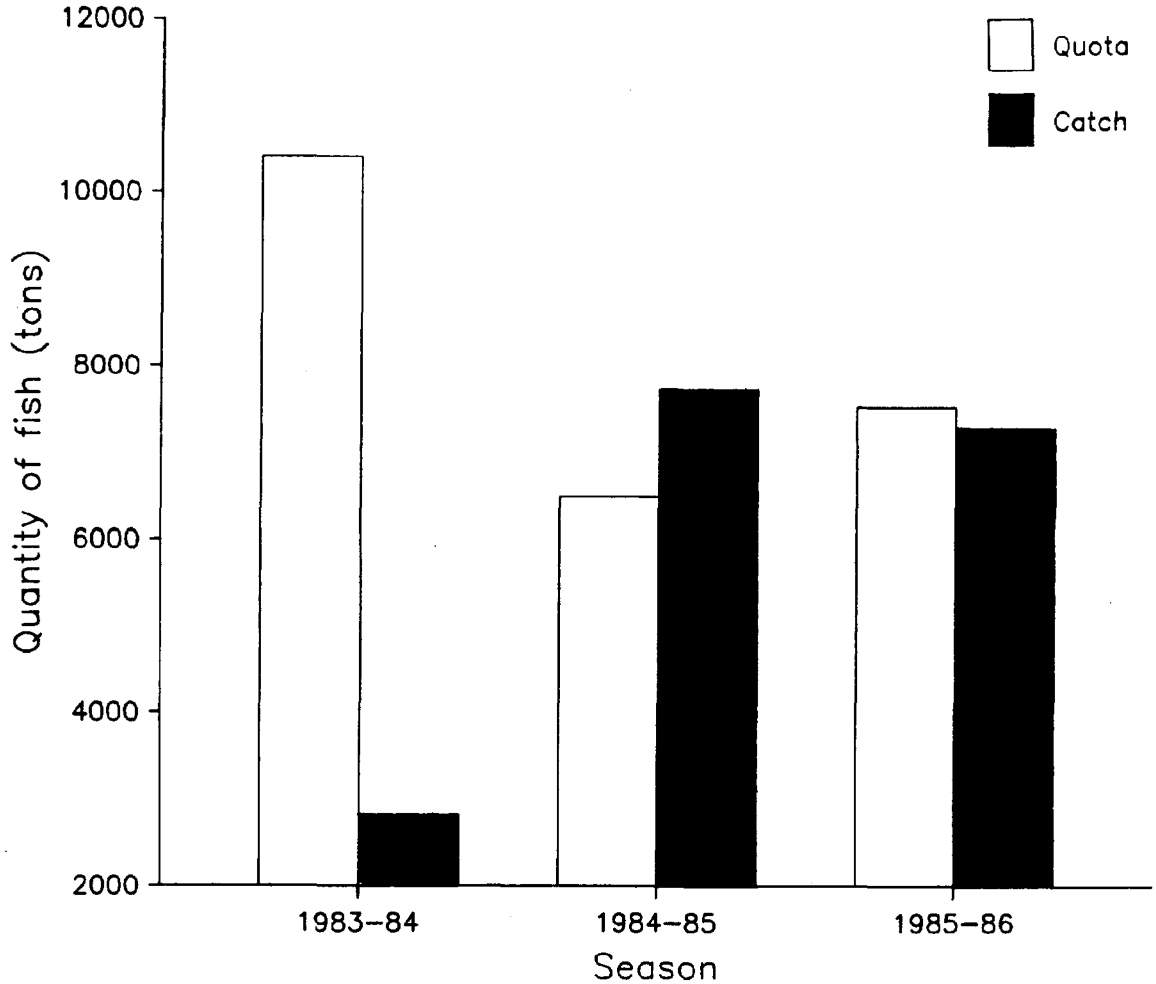


Figure 5.2. Total quota and catch for the commercial herring fishery within San Francisco Bay for spawning seasons 1983-84, 1984-85, and 1985-86.

out of San Francisco Bay with tides and are caught within the Bay and in the coastal ocean from April through October. Anchovy are used primarily for bait in the San Francisco area, and landings average approximately 0.8 million pounds annually. Anchovy landings reflect the amount of fish packed for bait in an individual year, which is strongly tied to market demand. A lesser quantity of anchovy were packed in 1985 following the large amount of anchovy which were processed and frozen in 1984. Landings were down in 1983, as the size of anchovies were smaller during the period of anomalously warm water temperatures. The relatively large amount of fish packed in 1984 resulted from concern in the industry over the 1983 anchovy supply. Warmer-than-normal water temperatures in 1983 resulted in smaller-sized anchovies inshore, though larger anchovies were reported in some areas offshore.

The smaller-size anchovies, or "pinheads" were abundant in 1983. These fish, which averaged as small as 30 to 40 fish per pound in 1983, were below the size normally used for packing and freezing, which is between 20 to 28 fish per pound. Packers report the size of anchovies has shown a decrease over the last ten years. A packing rate of approximately 18 fish per pound was common in the period preceding the last ten years. Warmer-than-normal water temperatures over the last ten years along the California coast coincides with the same period of the apparent decline in the size of anchovies. Anchovy catches in the 1986 season appear to be good, with packing rates averaging 22 to 26 fish per pound.

Chinook salmon landings have shown a strong upswing following greatly reduced landings in 1983. In 1985, 2.1 million pounds of chinook salmon were landed, up considerably from the 1.5 million pounds landed in 1984. The increased salmon harvest of 1984 and 1985 is probably due in large part to the high spring runoff conditions in the central valley of California in 1982 and 1983. Water year 1983 was an extremely high runoff year in California (October 1982 - September 1983) with a Delta outflow of 64.5 million acre feet being the highest since accurate outflow records began in 1900. The high flows provided excellent survival of young salmon during rearing and out migration to the sea, hence more adults with more young. The Sacramento-San Joaquin Estuary Ecological Study Program has documented this observation in estuarine salmon studies. Chinook salmon was another important commercial species which showed reduced growth and moved from traditional fishing grounds following the 1982-83 ENSO event. The return of salmon which moved out of normal harvesting areas during the ENSO event may have contributed to the strong relative abundance of chinook salmon in 1984 and 1985.

5.4 Shellfish

The quantity of shellfish landed in the San Francisco area constituted 2 percent of the total landings of finfish and shellfish, representing a relatively small portion of the overall catch. Quantity and value of total shellfish landed in 1985 were 0.90 million pounds and $1.64 million (Table 5.6). These figures are very close to the 1984 figures of 0.96 million pounds and $1.74 million in value. Species which showed the largest quantities landed were dungeness crab and squid.

Dungeness crab landings remained low in 1984 and 1985 compared to the years prior to the 1960's when dungeness crab landings were a major portion of the area's total fishery landings. Dungeness crab studies by the California Department of Fish and Game indicate improved catches in 1986.

Shellfish harvesting within San Francisco Bay has been limited to recreational collecting since the 1930s due to water quality problems, though a commercial fishery for the Bay shrimp, Crangon, presently exists. About 20 vessels participated in the bay shrimp fishery in 1984 and 1985. Most of the catch was sold as bait but some was sold for food. Log book records received by the California Department of Fish and Game from fishermen show approximately 90 tons of bay shrimp were landed primarily for bait in San Francisco Bay in 1984. Similar landings were made in 1985, but records are not yet totalled for that year.

Table 5.6. Commercial shellfish landings into the San Francisco Bay area, 1984-85.

	1984		1985	
Species	Pounds	Dollars	Pounds	Dollars
Crustaceans:				
Crab, dungeness	626,594	$1,272,750	585,385	$1,194,931
Crab, rock	36,709	28,399	47,100	40,064
Echinoderms:				
Urchin, sea	8,768	2,611	3,868	936
Molluscs:				
Abalone, unspecified	-	-	1,015	3,554
Abalone, red	52,957	365,810	80,735	363,694
Clam, unspecified	2,650	735	1,439	820
Mussel	6,567	6,218	7,944	7,629
Octopus, unspecified	3,801	2,244	1,026	612
Snail, Sea	5,559	4,690	-	-
Squid, market	213,769	54,950	169,668	23,469
Totals	960,058	$1,741,123	899,533	$1,638,859

Data from California Department of Fish and Game. Landings for species of less than 1,000 pounds reported are not listed individually. Blank indicates data not available or none reported. Figures for 1985 are preliminary.

5.5 Blooms

U.S. Geological Survey studies of phytoplankton blooms in San Francisco Bay show marked seasonal variations in Suisun Bay, compared to the south bay. Prolonged summer blooms are strongly influenced by river flow in Suisun Bay. Blooms in the south Bay, which are less directly influenced by river discharge, occur in late March or April, depending largely on the degree of water column stratification in the lagoon-type south bay. Phytoplankton concentrations in San Francisco Bay are termed blooms when observed concentrations rise considerably higher than normal background concentrations for an area. Blooms in the south bay are usually considered to have concentrations of 10 micrograms per liter or higher of chlorophyll. In Suisun Bay, heavy phytoplankton concentrations are usually considered blooms at a minimum of 15-20 micrograms per liter of chlorophyll.

Over the last three years, blooms in the south Bay peaked on March 29, 1985; April 10 and 19, 1984; and April 8, 12, and 15, 1983 (Table 5.7 and Figure 5.3). Highest average concentrations of phytoplankton were observed in 1985, compared to the previous two years. Normally, in south bay, changes in tidal energy may be used to indicate approximately the timing of the bloom event. A prolonged reduction in the range between high and low tidal cycles coincident with high discharge from the Delta usually coincides with increased water column stratification. In 1985, the potential for blooms in south bay existed twice, from March 15-29 and April 15-30, though phytoplankton was at bloom levels only in the March window. Low river flow and reduced stratification may have contributed to the absence of the expected bloom in April 1985 in south bay. River flow into the San Francisco Bay system was much lower than normal in 1985, including the months preceding the spring bloom period, and notably in March (see Section 4.1, Streamflow).

Satellite imagery for March 22, 1985 shows high chlorophyll-a concentrations in near-surface water over wide areas of the south bay (Figure 5.4). The observations in the south bay appear to be consistent with data collected by the U.S. Geological Survey (USGS) on March 21. USGS found 3 micrograms per liter in the northern reaches of the south bay channel, increasing to 10-13 micrograms per liter along the channel in the southern reach, and in the mid-south bay further increasing to 40 micrograms per liter onto the eastern shoals of the south bay.

Phytoplankton growth in San Pablo Bay showed a typical pattern with early year growth in late winter-early spring. Sampling during this period by the California Department of Water Resources showed typical growth in the north shallows of San Pablo Bay with no activity in the channel. Sampling in Suisun Bay showed evidence of bloom conditions during a two-week period in early July 1985. The low flow conditions in 1985 indicated the potential for better phytoplankton growth in Suisun Bay, though no large increases in production were detected, and reasons for this are unclear at present.

Table 5.7. Dates of maximum phytoplankton bloom events in south Bay with peak chlorophyll-a concentrations, 1983-85.

Year	Date of maximum bloom	Peak concentration* (Micrograms/liter)
1983	April 8	20.7
	April 12	17.4
	April 15	18.0
1984	April 10	10.3
	April 19	13.2
1985	March 29	26.3

Data from U.S. Geological Survey, Water Resources Division, Menlo Park.
*Peak concentrations are average values for surface chlorophyll-a at 9-11 stations covering most of the south bay channel area.

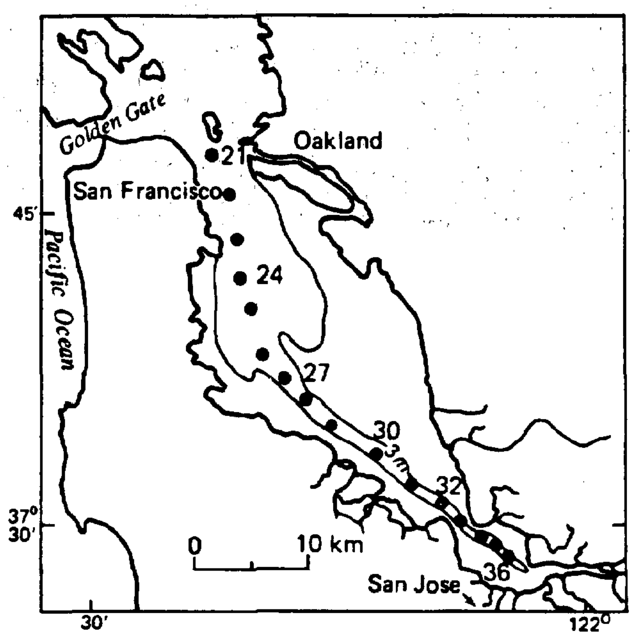


Figure 5.3 Map of south San Francisco Bay showing USGS sampling locations. Vertical profiles were taken at the numbered stations along the south bay channel.

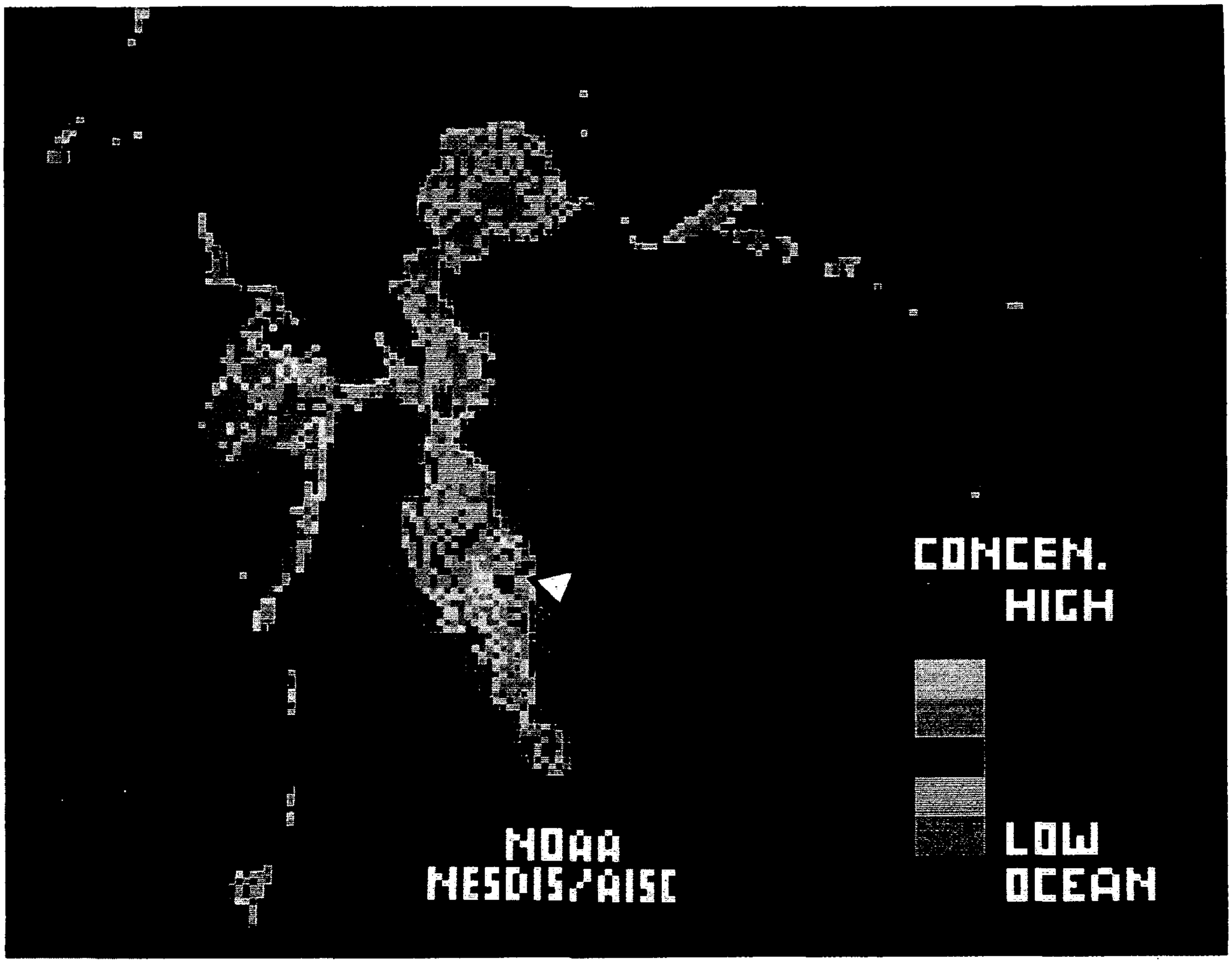


Figure 5.4. Satellite image of San Francisco Bay on March 22, 1985 during the annual spring phytoplankton bloom period in the south Bay. The image shows relative concentrations of chlorphyll-a and phaeopigments using Coastal Zone Color Scanner data. Red and near infrared bands are used in the analysis in order to detect pigment changes in turbid water. Green denotes high concentrations of 20-40 micrograms per liter based on in-situ data. Dark blue denotes very low (less than 1 microgram per liter) oceanic concentrations. The satellite data show low concentrations in San Pablo Bay and the northern reaches of the south bay. Concentrations increase in the southern Bay and increase further on the eastern shoals of the southern bay. The apparently low values along the axis marked by the arrow are probably due to some localized haze.

6. RECREATION

6.1 Summary of Recreational Activities

San Francisco Bay is an area well suited for many forms of marine recreation. Year-round outdoor activities in the area are encouraged by mild winters, summers with light breezes, warm autumns, and sunny, breezy springs. Chilly weather and hot spells are quickly tempered by the Bay and the Pacific Ocean. But should the weather prove inhospitable, residents and tourists can frequently escape to some other weather regime. For example, when, in July, it is cool and foggy at Stinson Beach, it may be warm and sunny in Oakland. A change of desired recreation may be necessary, but one can still enjoy the outdoors. Section 3.1 gives a summary of the type of weather that prevails around the Bay.

The Bay is the center of outdoor recreational activities. Some activities like boating, sailing, fishing, surfing, sailboarding, and swimming are water-contact sports. Others like bird-watching, whale-watching, walking, hiking, biking, golfing, kite-flying, sightseeing, outdoor games, and open-air theater and concerts simply use the bay as a favored setting.

The recreational variety in San Francisco Bay has made it an area particularly appealing to tourists. Celebrated in song and story as a picturebook city by the Bay, the San Francisco area attracts millions of tourists each year who fan out through the adjacent attractions such as the Redwoods, Yosemite National Park, and Lake Tahoe. The San Francisco Convention and Visitors Bureau reports that tourists usually cite the weather and the scenery as among the things they like most about the area.

With recreation so important to the San Francisco way of life, its economic impacts are likewise significant. While these impacts are not always studied or tabulated, they may be inferred from the evidence of degree of recreational activity. The significance of the Bay both to an area lifestyle and to the regional economy has been one of the driving forces in efforts to clean up the Bay, provide open spaces for future outdoor pursuits, and establish open access to waterfront areas. An early version of the California Outdoor Recreation Plan found that 60 percent of the public prefers recreational activities with a water orientation, even where water contact may not be part of the activity. Planning for the expansion of recreational facilities is important at both the city, county, and state level in the Bay area.

The San Francisco Bay climate with its usually mild winters makes for long seasons for most outdoor pursuits and facilities usage is frequently tied to a seasonal pattern. For the most part, except at the ocean beaches, overall usage statistics are not strongly impacted by daily weather changes. However, long periods of unusually warm or cool, rainy weather will show up in attendance surges or declines for particular recreations. 1985 was a warm, dry year with an unusually warm February particularly in the last half of the month; a warm early April; and a hot July. November was unusually cool, but not severe. Storm events were not significant during the year.

In this section, we will discuss various recreations in the San Francisco Bay area will develop as its central point seasonal pattern for each activity and the economic impacts associated with the form of recreation. 1985 will be considered in terms of how it varied from the normal pattern. The overall relation of marine environment to the development of specific recreational activities is considered in order to show the value of San Francisco Bay to the regional economy.

6.2 Park Attendance

Most parks in the San Francisco Bay area have a long season with highest activity between April and October. However, these parks enjoy substantial usage even during the winter and early spring owing to San Francisco's moderate climate. In some years, warm spells for parts of the winter months encourage even greater park usage. Parks in the area exist under every type of jurisdictional arrangement-- city, county, State, Federal, and even special park districts like East Bay Regional Park formed by several counties on the east side of the Bay. Facilities may range from small grassy areas beaches, fishing piers, lakes, picnic areas, riding trails, or hiking trails to a specialized facility like an old mine.

State Parks

State park attendance in the San Francisco Bay area, for the most part, showed increases during 1985 which were traceable both to population growth and a warm, dry year. Figure 6.1 shows the location of the selected state parks used in this study. Figures 6.2a-d depict the monthly attendance at these parks for the years 1983, 1984, and 1985. The park having the largest attendance gain was Candlestick, which is under development. From 1984 to 1985 visitations there grew by 80 percent. All the parks showed attendance gains in February which may be traceable to the unusually warm weather in the last half of the month. Mount Tamalpais had the greatest increase for the month of any of the four parks, a 93 percent spurt from 63,735 in 1984 to 122,699 in 1985.

Golden Gate National Recreation Area (GGNRA)

Golden Gate National Recreation Area, formed in 1972 from land in both San Francisco and Marin Counties (Figure 6.1), has the largest annual attendance of any of the U.S. national parks. Created with the basic concept of putting parks where people live and work, GGNRA may be accessed by public transportation or, for some San Francisco residents, it may be a short walk away. Parts of the park are adjacent to some of the more popular tourist areas in the city. Within its boundaries are a wide variety of recreational facilities, including Aquatic Park; Alcatraz Island; Muir, Ocean, and Stinson Beaches; Fort Point National Historic Park, Hyde Street Pier and Historic Ships; and the National Maritime Museum. Attendance is most numerous in the summertime, which corresponds to the height of both the tourist season and the beach season (Figure 6.3). Attendance at GGNRA increased 10 percent from 1984 to 1985 rising from 16.7 million to 18.4 million visits.

GGNRA is large enough so that weather in different parts of the park may vary. Inclement weather also impacts different recreational activities

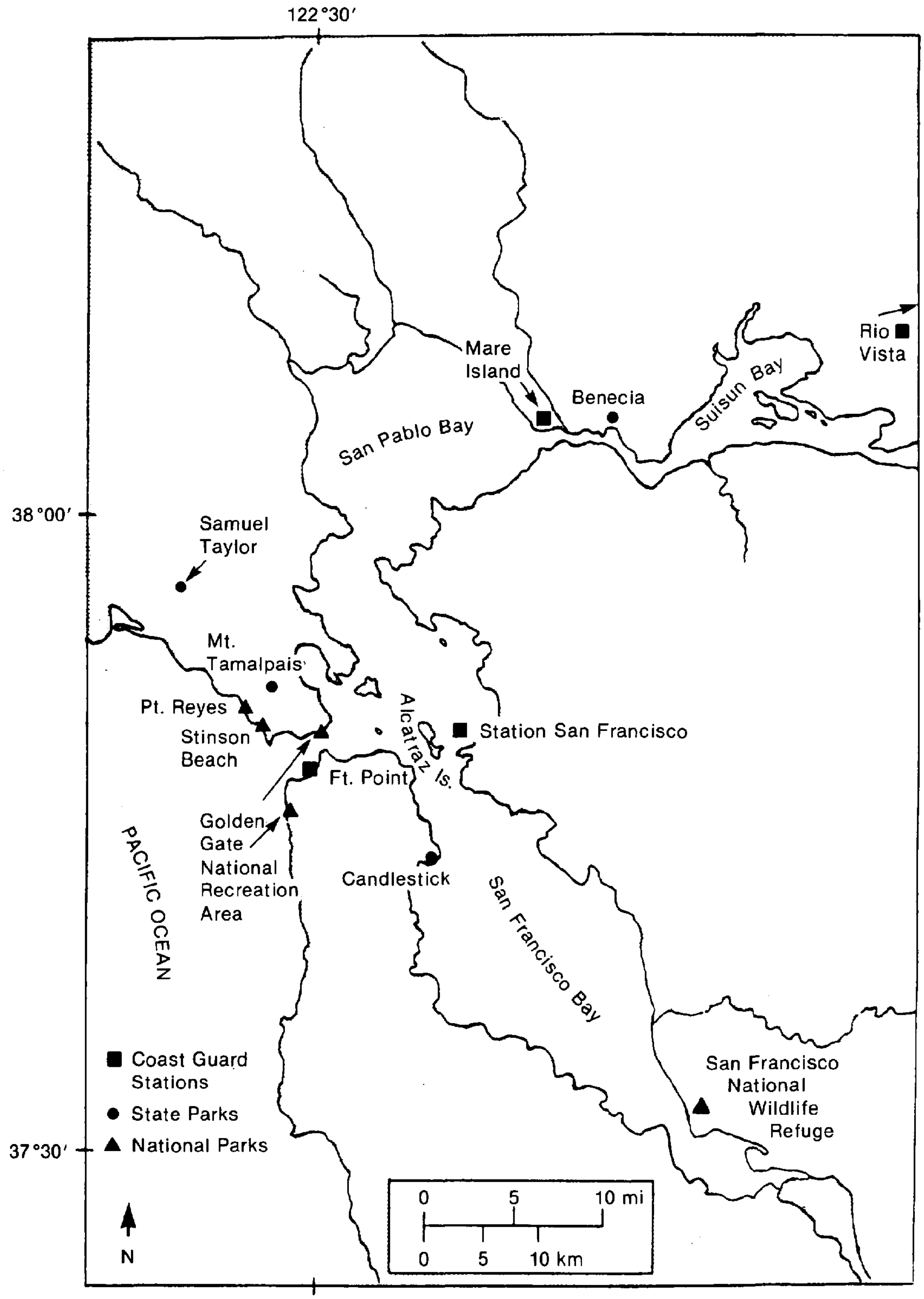


Figure 6.1 Locations of state parks, national parks and Coast Guard stations used in this study.

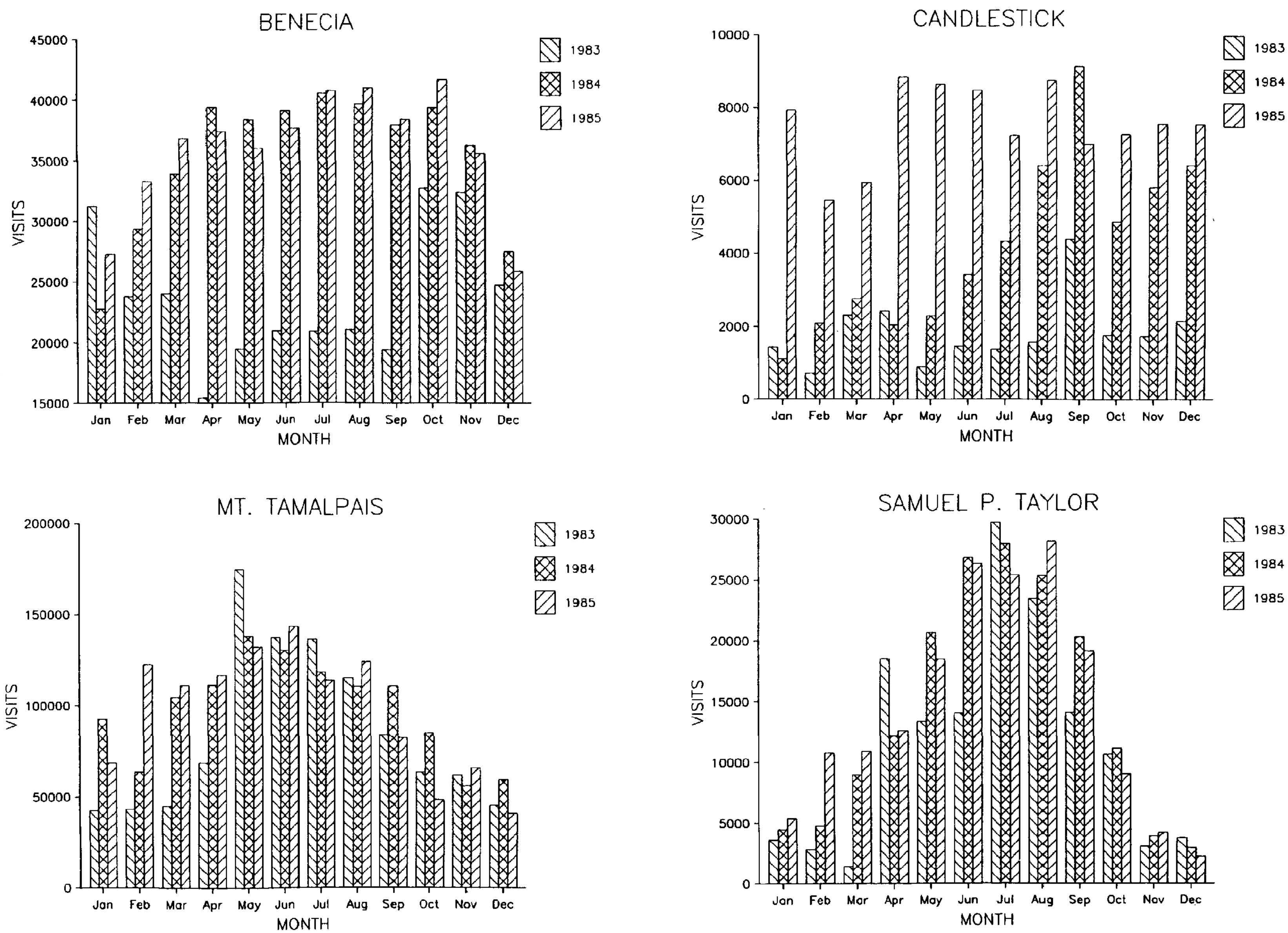


Figure 6.2(a-d) Number of visits to selected state parks in the San Francisco Bay area, by month, 1983-85.

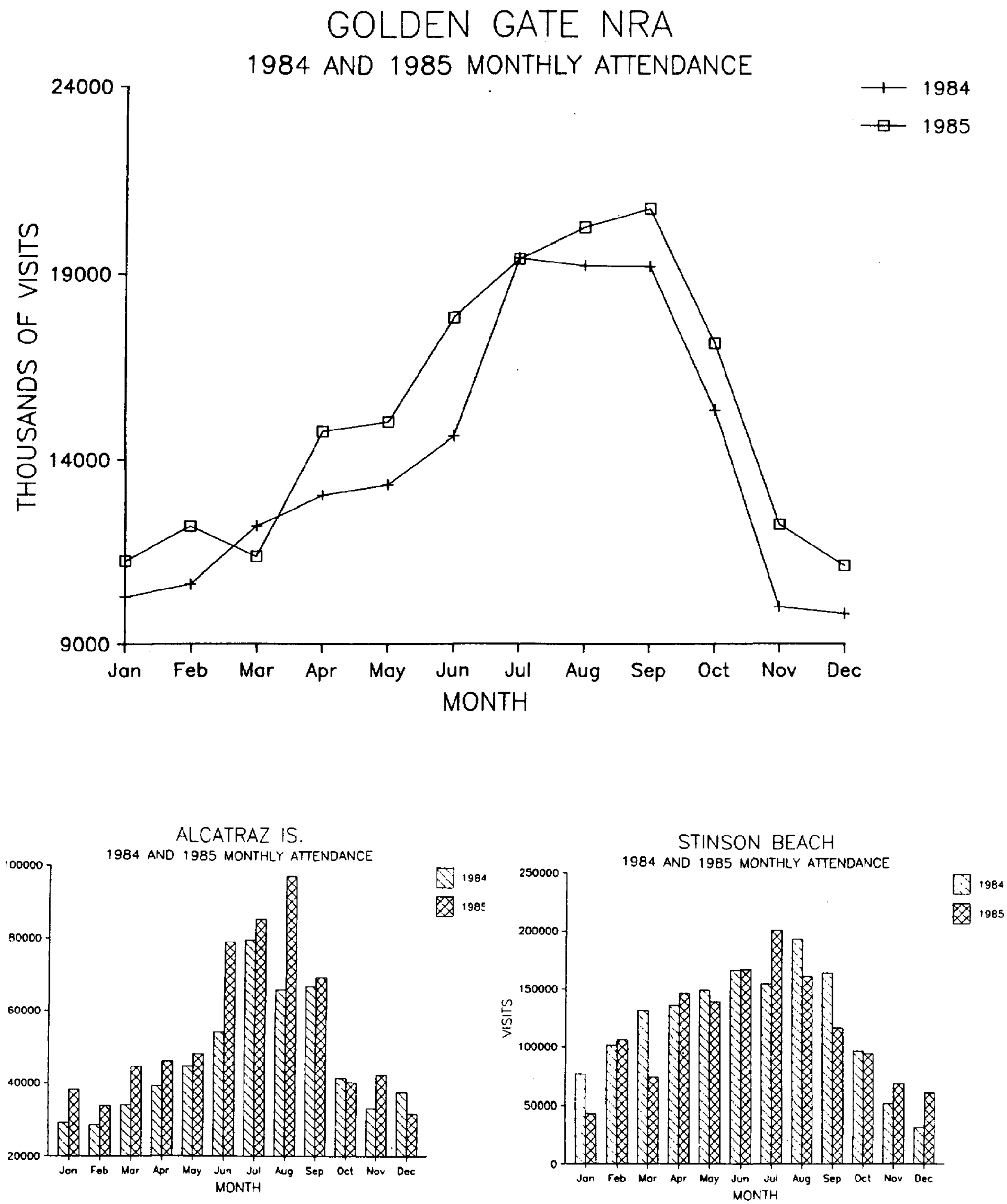


Figure 6.3(a-c) Number of visits to (a) Golden Gate National Recreation Area, (b) Alcatraz Island, and (c) Stinson Beach, by month, 1984 and 1985. Source: National Park Service.

differently. Early morning rain and fog at a beach generally affects attendance all day since many people set out for beaches early. Similar weather when other recreational pursuits are anticipated may mean people just go on with the recreation or wait until the weather improves to begin. Stinson Beach, located to the north of Golden Gate Bridge, is subject to weather patterns set up by the ocean upwelling that occurs in the spring and summer months. During this period, rain and fog commonly shroud the beach.

Alcatraz Island, located in the interior of the Bay, is somewhat protected from these coastal influences but is subject to fog and strong Bay winds. During 1985, visits to Alcatraz Island, the site of the former Federal penitentiary, showed strong monthly increases while Stinson Beach showed declines. Figures 6.3b and c depict the differences between 1985 and 1984 for each month for both visitor sites. While Alcatraz Island was experiencing an 18 percent increase in attendance, Stinson Beach was experiencing a 5 percent decline. The only summer month in 1985 in which Stinson Beach had a large attendance increase was July. Alcatraz Island attendance increased in almost every month, with a 48 percent increase in August, a month in which Stinson Beach had a 16 percent decline.

6.3 Recreational Fishing

Recreational fishing in San Francisco Bay is a year-round activity and many species, like sturgeon and rockfish (also known as rock cod or Pacific red snapper), are caught throughout the year. Other species have preferred seasons. Striped bass is best caught between May and November, and salmon fishing is excellent from late winter through midfall, depending on the status of the stocks. stocks.

Fishing is conducted from beaches, piers, private recreational boats, party/charter boats, bridges, and other vantage points. Ocean fishing takes place from beaches, private recreational boats, and party/charter boats.

The number of recreational fishermen in the San Francisco Bay area may be inferred from the numbers of striped bass stamps sold by the California Department of Fish and Game. Striped bass is a popular sportfish to local residents and is a preferred catch. In order to fish for striped bass, a person must have a stamp affixed to his/her fishing license. Since the bay, the rivers that enter it, and the nearby ocean are the only California locations where striped bass are found, the numbers of these stamps sold give a good indication of the number of recreational fishermen in the area. The numbers of these stamps sold from 1983 to 1985 are shown on the next page. Thus, there are well over a half-million recreational fishermen in the San Francisco Bay area. A direct indicator of the economic impact of this is the purchase of the striped bass stamps in 1985 which was $3.50 and had to be affixed to a license which cost $13.75. Other direct impacts would be found in the sales of rods and reels and bait; boat sales, maintenance, and fuel; charter boat fees; transportation to take part in fishing; and the like. A study done by Meyer Resources, Inc. for the California Department of Fish and Game found that in 1983 that the estimated direct profit from sport fishing of striped bass for California businesses was about $21 per fish caught. Total income generated per fish was estimated to be about $258.

Sales of Striped Bass Stamps, 1983-1985.

Year	Number of Stamps Sold
1983	538,994
1984	598,504
1985	568,384

Data from California Department of Fish and Game. 1985 figure is preliminary.

Charter/party boats which work out of the San Francisco and the San Francisco Bay-Delta area have their highest numbers of passengers during the traditional vacation months of July and August. According to a spokesman for one of the large sportfishing associations in the area, the passengers are primarily residents of the area. Despite the fact that the highest number of passengers are carried in the summer, the interest of sportfishermen on these boats is dominated by the desire to catch salmon. This fishery is best in early spring when the salmon are making their spawning runs but excels between late winter and early fall. However, salmon are caught throughout a large portion the year and charterboat catches of salmon are taken in the ocean. A typical day trip for salmon fishing in 1985 average was about $30 per person. Table 6.1 shows the distribution of charterboat catches for 1982 through 1985. Despite the interest of sportfishermen in salmon, charter fishing boat catch statistics indicate that rockfish in the dominant catch. The importance of the salmon fishery is shown in the relation of catch statistics to number of anglers (Figure 6.4) In 1983 when salmon runs were poor, number of anglers carried also dropped, falling 12 percent between 1982 and 1983. As salmon abundance increased in 1984 and 1985, number of anglers also increased, rising by almost 40 percent over the two years. The economic benefit to charterboat operators and to other businesses that cater to anglers from the increase in salmon runs thus appears to be quite substantial.

6.4 Recreational Boating and Sailboarding

Boat Ownership

The ownership of recreational boats continues to expand in the 9-county area surrounding San Francisco Bay. Growth in number of registered boats increased 4 percent from 1984 to 1985 paralleling the growth rate in the state of California (Table 6.2), but slowed down moderately from the rate of increase in the previous year. These registration figures include sailboats over 8 feet and all motorboats. Weather plays a significant part in stimulating recreational boat use in San Francisco Bay with the boating season starting in early spring and extending into late fall, and when winters are mild, going on into winter. For example, when storms are not affecting Bay weather, fall and winter

Table 6.1. Number of fish caught by the California charter fishing boat fleet, San Francisco and San Francisco Bay-Delta, 1982-1985.

Species	1982	1983	1984	1985
Bass, striped	2,743	14,053	13,499	9,673
Bonito, Pacific	2	13,774	237	0
Cabezon	688	327	244	475
Croaker, white	144	87	741	785
Flatfish, unspec.	794	1,433	1,938	586
Halibut, California	2,287	3,515	1,023	1,026
Lingcod	5,193	5,456	5,537	3,606
Mackerel, Pacific	3,002	15,576	11,643	3,474
Mackerel, jack	128	1,009	571	307
Rockfish, unspec.	69,721	127,572	146,487	103,294
Salmon, unspec.	92,876	49,200	65,707	90,240
Sturgeon	613	715	526	765
Tuna, albacore	57	1,673	1,190	2,218
All others	1,346	1,736	2,209	1,819
Totals	179,594	236,126	251,532	218,268

Data from California Department of Fish and Game. 1985 figures are preliminary.

Table 6.2. Recreational boat registration in counties surrounding San Francisco Bay, 1983-1985.

County	1983	1984	1985
Alameda	25,688	27,662	28,685
Contra Costa	26,173	28,201	29,733
Marin	7,409	8,357	8,552
Napa	4,650	4,907	5,311
San Francisco	3,932	4,306	4,436
San Mateo	12,513	13,719	14,179
Santa Clara	29,053	30,949	31,582
Solano	8,840	9,313	9,844
Sonoma	9,731	10,447	11,324
Bay Area Totals	127,989	137,861	143,646
Percent change		+7.7	+4.2
California Totals	559,964	609,538	634,119
Percent change		+8.8	+4.0

Data from California Department of Motor Vehicles.

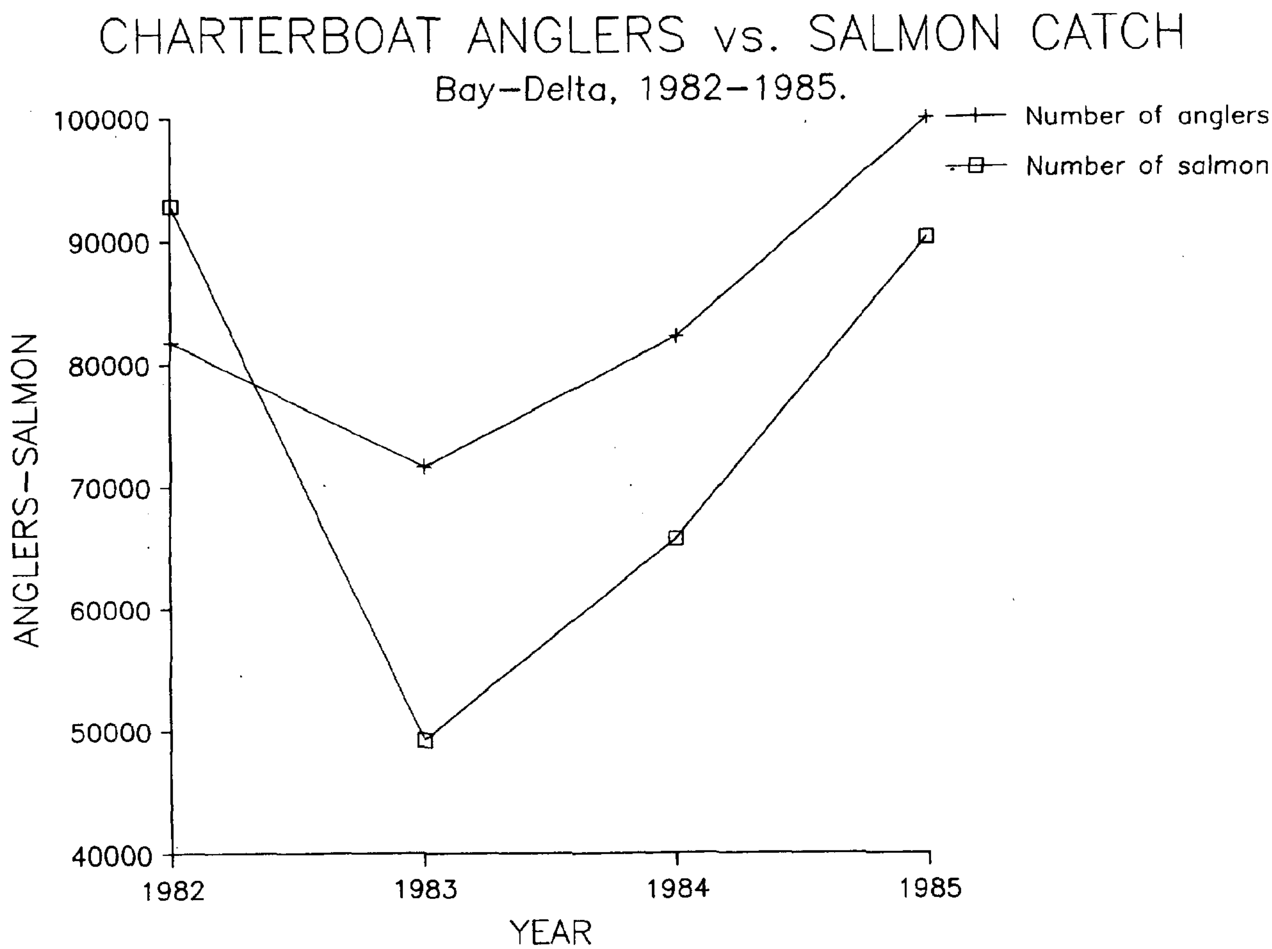


Figure 6.4 Number of salmon caught and number of commercial fishing boat passengers, San Francisco and San Francisco Bay Delta, 1982-85. Source: California Department of Fish and Game.

afternoons offer good sailing conditions in exposed waters. Strong storm-generated winds can reach 40 to 60 knots in gusts, but sustained winds of gale force are uncommon inside the Bay. Late spring is the windiest time of year. But from April through fall pleasant conditions for sailing (winds of 15-20 knots; 60°F air temperatures) usually abound. Sailing around Golden Gate is particularly popular. Powerboating is a recreation participated by people with incomes above the household median income. The purchase of the boat represents only the first stage of economic impact. Expenditures for trips, boat upkeep, and marina/launching fees form a still larger area of economic stimulation for the regional economy since they continue over a number of years. Thus the large amount of boat ownership in the San Francisco Bay area indicates substantial economic impacts from the Bay's climate.

Marina facilities

Figure 6.5 shows the locations of boating facilities around the Bay. A factor influencing marina distribution has been boater preference to have a marina near home. San Francisco, the East Bay shoreline from Alameda to Richmond, and Marin County have two-thirds of the available berths (3 miles of the Sausalito waterfront and 3 miles along each side of the Oakland Estuary are largely occupied by marinas) and the remaining third are scattered around the Bay. Sailboat marinas tend to be located in the Central Bay in Marin, San Francisco, and Alameda Counties. These locations are nearer to preferred sailing areas. Powerboat marinas are usually located in the South Bay and east of the Carquinez Bridge near areas offering good cruising, smoother waters for waterskiing, and good fishing. The Delta area (not fully shown in Figure 6.5) contains a large number of popular boating facilities.

Marine Advisories

The number of marine advisories (small craft advisories, gale warnings, and storm warnings) issued by the National Weather Service gives a good indication of the bay wind/weather patterns. Such advisories are issued as needed along with any of the four forecasts that are made each day for the Bay area. Bay winds are strongest through the Golden Gate and other mountain gaps. Since strong gusty winds can be hazardous small recreational craft, these specialized weather advisories are important in the Bay. According to a National Weather Service forecaster, 1985 proved to be a normal year for the distribution of these advisories, which are shown in Table 6.3. They indicate some of the usual weather patterns experienced in the Bay area by boaters. The months with the largest number of advisories were March and April, the months that are traditionally windiest in the Bay. March was the month with the largest number of gale warnings. Conditions are calmer in June, July, August, and September; however traditional westerlies can lash San Francisco Bay with 20-30 knot winds in this season. Winter storms with their stronger winds occur again in October and extend in throughout the winter are evidenced by the large number of advisories in these months.

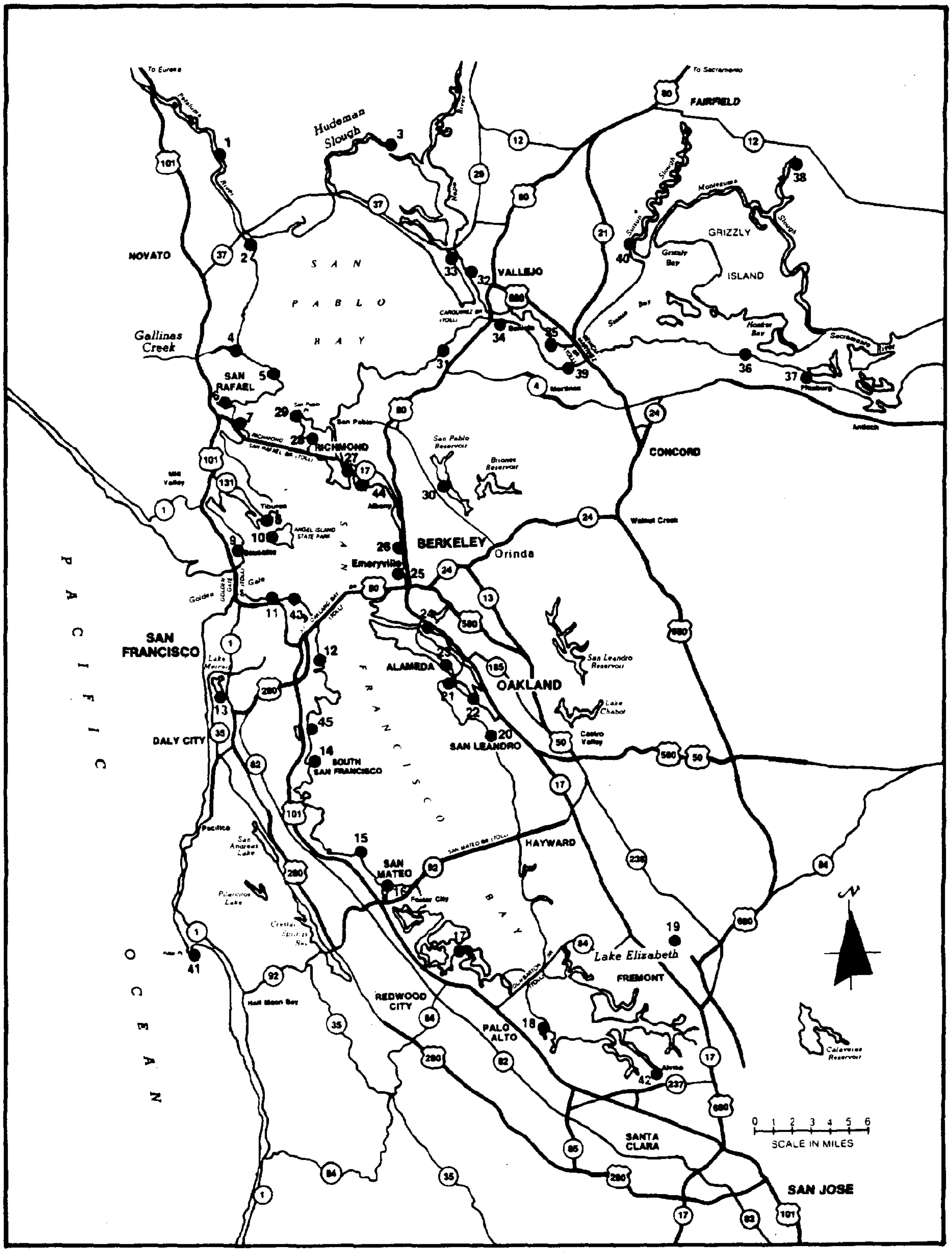


Figure 6.5 Locations of boating facilities, San Francisco Bay. Blackened circles indicate facilities. Map obtained from California Department of Boating and Waterways.

Table 6.3. Recreational marine advisories issued by the National Weather Service for the San Francisco Bay Area, by month, 1985.

	Type of Advisory			
Month	Small Craft	Gale Warning	Storm Warning	Month Total
January	31	2	0	33
February	35	7	0	42
March	42	12	0	54
April	53	4	0	57
May	39	2	0	41
June	19	2	0	21
July	25	5	0	30
August	26	2	0	28
September	18	0	0	50
October	46	4	0	50
November	44	2	0	46
December	37	3	0	40
Totals	415	45	0	460

Small craft advisory = winds 20-33 knots
Gale warning = winds 34-47 knots
Storm warning = winds 48 knots and above

Data from National Climatic Data Center, NOAA.

Search and rescue operations

Statistics on search and rescue operations conducted by the U.S. Coast Guard are an indirect indicator of the degree of boating activity in any month. In San Francisco Bay, where such operations are conducted by the Coast Guard from four stations (Figure 6.1), they are also an indicator of the degree of boating activity in different parts of the Bay. These statistics for 1985, which are presented in Table 6.4, indicate that highest levels of boating activity in the Bay are from June through September with the lowest levels of activity in January and December. Also, it appears that most boating activity congregates around the mouth of the Bay, the area serviced by the Fort Point and San Francisco stations. Together these two stations handled over 60 percent of the caseload in the Bay and nearby ocean. It is also the area that presents the most navigational problems for small boats--winds, currents, commercial ships, and fog.

Statistics on recreational boating accidents are collected by the California Department of Boating and Waterways. An indication not only of the seriousness of boating accidents in San Francisco Bay but also of their economic impacts is shown in Table 6.5. It contains data on the annual number of accidents in

Table 6.4. Search and rescue operations, U.S. Coast Guard, San Francisco Bay stations, by month, 1985.

Month	Fort Point	Mare Island	Rio Vista	San Francisco	Total Month's Caseload
January	19	14	15	27	75
February	31	25	25	41	122
March	31	19	37	45	132
April	25	25	29	57	136
May	39	28	54	56	177
June	39	30	59	81	209
July	58	29	59	66	212
August	64	42	39	57	202
September	52	25	29	41	147
October	54	16	29	36	135
November	33	21	22	32	108
December	26	17	11	26	80
Totals	471	291	408	565	1735

Data from U.S. Coast Guard.

Table 6.5. Numbers of reported recreational boating accidents, injuries, fatalities, and damages; San Francisco Bay; 1983-85.

Year	Accidents	Fatalities	Injuries	Damages (thousands of $)
1983	74	27	21	494.4
1984	103	21	19	302.1
1985	109	45	12	920.5

1983, 1984, and 1985; the number of injuries and fatalities from these accidents; and the dollar damage to property involved. From 1983 to 1985, the number of accidents increased by 47 percent, from 74 to 109. 1985 was a costly year in terms of damages with over $920,000 lost in reported boating accidents.

Sailboarding

A water-contact sport that is developing in the San Francisco Bay area at a brisk pace is sailboarding. Riding a large surfboard with a sail or mast, the sailboarder seeks out waves and winds that challenge his/her skills. Unlike sailboaters who go back to their moorings or berths when small craft advisories are issued, experienced sailboarders delight in windy conditions. One estimate of the number of sailboard enthusiasts in the San Francisco Bay area put the current figure at between 6,000 and 10,000. A series of shops around the Bay have sprung up to meet the needs of the sport. Clothing and equipment to participate in it may range from $750 for basic supplies to $2,500 for an elaborate rig.

6.5 Wildlife Observation and Use

The waters and marshes of San Francisco Bay and the ocean outside the Bay are the home or place of temporary passage for a large variety of birds, waterfowl, and marine mammals. The Bay is on the Pacific flyway between Canada and areas to the south and attracts a variety of overwintering birds. Many wildlife refuges, both public and private, are located on or near the Bay. The ocean teems with seals, sea lions, and migratory whales. Given the great interest in outdoor recreation in the Bay area and the vocally expressed interest of many groups in the study and preservation of nature, observation of wildlife in the Bay area has become a major recreational pursuit and one that has enriched the economy. There is also an interest of another segment of Bay residents in the hunting of waterfowl and game.

Bird-watching

Bird-watching has become one of the nation's most popular passive sports. A survey taken in 1980 by the U.S. Fish and Wildlife Service indicated that nearly 26 million people in the U.S. had bought birdseed and that 16 million bought or had film developed related to the nonconsumptive use of wildlife. A survey by the State of California in the same year cited nature appreciation as one of the high-expenditure, rapid-growth recreational activities. Among the things bird-watchers buy as the hobby develops, following birdseed and film and developing, are cameras, camping equipment, binoculars, and field guides. Even more serious hobbyists might add such items as field trips to distant places.

The growing popularity of bird-watching and other forms of nature appreciation is evident in the increasing attendance statistics at the San Francisco Bay National Wildlife Refuge. From 1984 to 1985 visits to the refuge grew by 20 percent, from 132,680 to 159,283. The seasonal pattern of attendance indicates low attendance months in January and February with a continuing growth in the number of visits into the summer and fall. Attendance changes are usually caused only by exceptionally cold or exceptionally warm months. For example, February 1985 visits soared nearly 29 percent over those in 1984 (Figure 6.6a). The second half of February 1985 was unusually warm, making visits to the refuge particularly attractive. Attendance surges in the fall may coincide with the migration of birds and increasing interest in them rather than weather. Such appears to be the case from October through December 1985 when visits increased substantially over those in 1984. A small number of visits to the refuge from October through January, generally less than 5 percent, are devoted to hunting.

In 1985 the U.S. Fish and Wildlife Service published a draft survey concerning contaminant issues in national wildlife refuges which categorized these refuges by the types of actions needed to be taken. The San Francisco Bay National Wildlife Refuge was identified as being increasingly threatened by industrial pollution, sewage treatment plants, urban runoff, and solid waste landfills. High selenium levels had been documented in ducks (scoters) collected from the bay. The refuge was placed in a Class "C" grouping for action, that is, a refuge with a problem requiring additional reconnaissance monitoring. In addition to these findings, the California Department of Fish and Game found elevated levels of selenium in two species of waterfowl taken from Suisun Bay early in 1986.

Duck Hunting

Duck hunting is a popular recreation on Suisun Marsh. In fact, the marsh is managed primarily to provide an attractive habitat for migratory waterfowl. The area also abounds in opportunities for the hunting of upland game. Several public facilities and over 150 private duck clubs offer opportunities to pursue these sports. Duck-hunting season ranges from October through January. Demand for duck-club membership is high and duck hunting appears to be an increasingly popular recreation, although the actual numbers of people who engage in it do not appear to be large. Duck hunters stimulate the regional economy with sizable expenditures for guns, boats, decoys, binoculars, and other clothing and equipment used in the sport. A 1984 study by the California Department of Parks and Recreation found hunting to be the highest-expenditure recreational day in the state.

Whale-watching

The annual migration of the gray whale is a popular event along the coast of California. Traveling from the Alaskan waters to the Sea of Cortez spawning grounds from January through February and returning from February through April, these whales have increasingly stimulated popular interest and have spawned the development of a California whale-watching industry. In 1978, the National Marine Fisheries Services estimated that about 197,000 individuals had taken part in whale-watching during the 1977-78 gray whale migration. It has been estimated that the gross income from boat expeditions to take part in whale-watching in the 1983-84 season exceeded $2.6 million. This figure unquestionably understates the true economic impact on the regional economy since it does not include meals, travel, lodging, and the purchase of books and other items relating to whales. In addition to whale-watch cruises, the migration is observed from coastal overlooks by large numbers of people.

In the San Francisco Bay area, most whale-watching operations are conducted out of Half Moon Bay, south of San Francisco. This is because the migrational route taken by the whales avoids the mouth of the Bay causing a much longer boat trip from the landings to places of potential whale sightings. Trips from the area are among the most expensive whale-watching trips along the California coast, ranging from $15 to $25 per adult. While whale-watching trip operators employ a wide variety of vessels, such as inland ferries, sportfishing boats, and sightseeing boats, vessels are increasingly being built specifically for the whale-watch service.

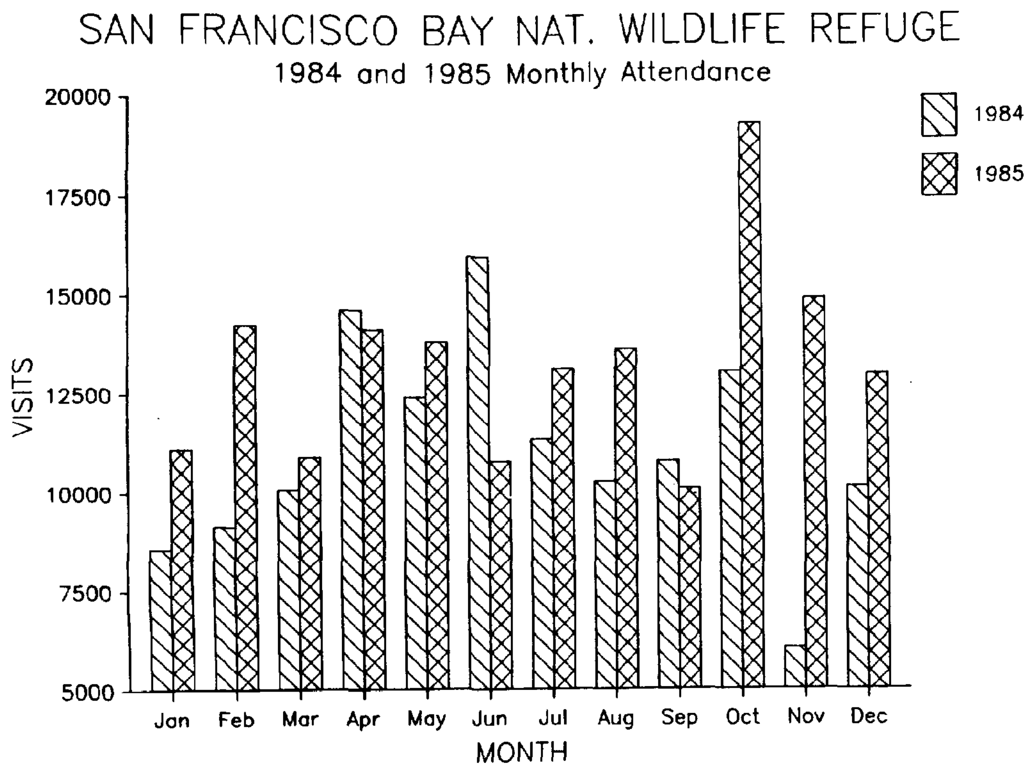
Stormy and cool weather in the ocean near San Francisco during the whale-watching season is common. The influence of weather can be seen in the ratio of trips scheduled to trips conducted. In the 1982-83 season, only 40 percent of the scheduled trips from the San Francisco Bay area were run due to the severity of the winter season. In 1983-84, a milder winter permitted 75 percent of the trips to be run. Periods of bad weather such as occurred in 1983-84 are enough to put marginal operators out of business.

Among the operators of tours from the San Francisco Bay area is the Oceanic Society, a national environmental organization dedicated to marine research, education, and policy development. They have been running guided whale-watch tours from Half Moon Bay for a number of years. Popularity of these cruises in the 1984-85 season and the 1983-84 season is shown in Table 6.6 which lists number of trips scheduled, number cancelled for undersubscription, number cancelled for weather-related causes, and total number of passengers carried. From 1983-84 to 1984-85 total number of passengers carried declined about 6 percent. This decline was was not weather-related since 7 trips were cancelled during the 1984-85 season and 13 during the 1983-84 season.

Table 6.6. Cruise data for Oceanic Society whale-watch trips from Half Moon Bay, 1984-85 and 1983-84 seasons.

Month	Trips Scheduled	Trips Cancelled (undersubs)	Trips Cancelled (weather)	Trips Aborted (weather)	Passengers Carried
1984-85:					
December	10	4	0	0	371
January	28	4	0	1	1506
February	28	0	1	0	1744
March	35	2	6	0	1674
April	27	12	0	0	858
Totals	128	22	7	1	6153
1983-84:					
December	9	3	1	0	259
January	35	2	8	0	1533
February	28	2	0	0	1573
March	35	0	2	0	1954
April	20	3	2	0	977
May	6	2	0	4	226
Totals	133	12	13	0	6522

Data from the Oceanic Society, San Francisco, CA.



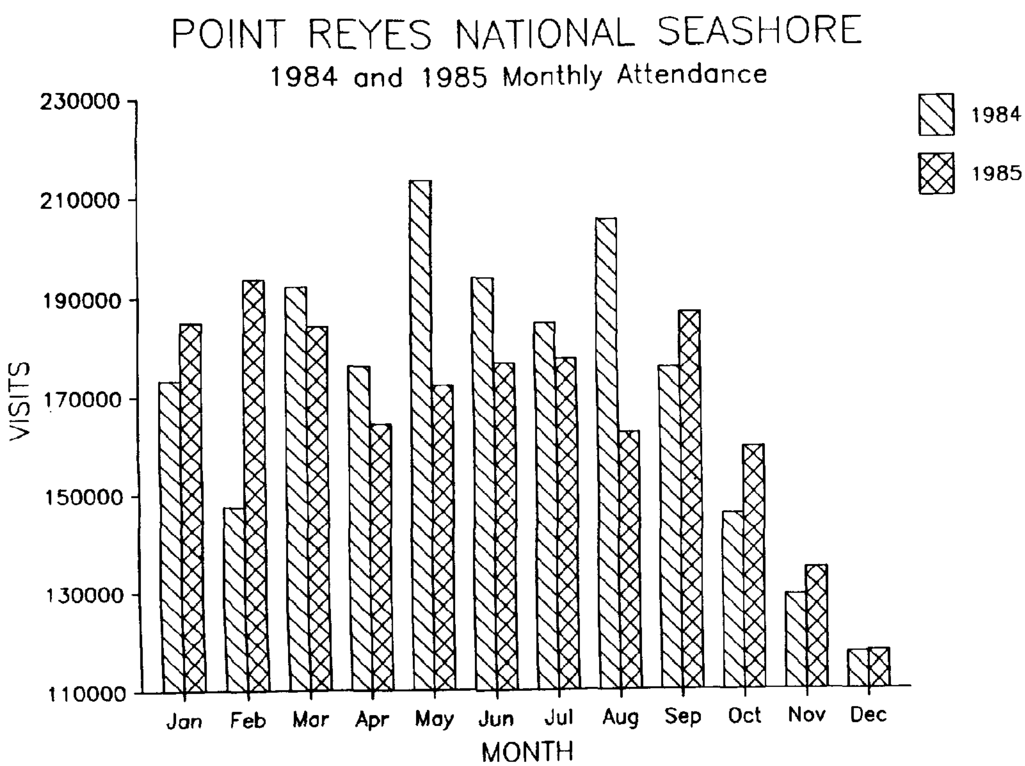


Figure 6.6 Number of visits to (a) San Francisco National Wildlife Refuge and (b) Point Reyes National Seashore, by month, 1984 and 1985. Source: U.S. Fish and Wildlife Service; National Park Service.

However, the 1983-84 season extended an additional month into May when people who had cancelled trips were given a chance to rebook.

During the 1985-86 season, the Oceanic Society began trips from San Francisco aboard an 87-foot catamaran designed specifically for whale-watch cruises. The popularity of this departure point compared to that of Half Moon Bay was immediately apparent. For the entire season, San Francisco cruises attracted 10,142 passengers while those from Half Moon Bay attracted only 1,259 people. While some of the residents whale-watchers may return to Half Moon Bay for future trips, the San Francisco embarkation point attracted more tourists than had previously been on these cruises.

Whale-watch tours, whether departing from San Francisco or Half Moon Bay, generally go north to Point Reyes lighthouse which is also the vantage point for a most of land-based whalewatching. Statistics on visitations for 1984 and 1985 at this national seashore were high in January, February, and March considering that this period near the ocean is cold and stormy and thus visitation might therefore be expected to remain at the November-December low levels. (Figure 6.6b).

The migrating whales not only provide regular recreational opportunities for residents of the Bay area, they sometimes also provide episodes of exceptional human interest. The immediate popularity of the humpback whale, nicknamed Humphrey, who on his migratory trip took a wrong turn at San Francisco Bay on October 11 and ended up near Rio Vista in the Sacramento River, is an example of the local fascination with marine wildlife. Humphrey was the subject of much interest as a series of rescue efforts unfolded. These efforts included the use of "oikomi," an acoustical method used to herd porpoises; recommendations by marine biologists on methods to be used in getting Humphrey out, which methods Humphrey confounded by continuing to swim in circles; and formation of a flotilla of 33 boats--mustered from military landing craft and Coast Guard and sheriff's patrol boats and from smaller, private vessels--designed to convince him to leave. Finally, biologists and sound experts played tape recordings of humpback feeding noises, while the boats steered the whale through the Bay.

The gigantic rescue effort was personally viewed by perhaps hundreds of thousands of area residents who jammed narrow vantage points and clogged roadways for a chance to see the drama unfold. News media from all over the country were on hand. Figure 6.7 shows some of the interest Humphrey received. Souvenir sellers, restaurants, gasoline stations, and other businesses profited from the event as did motels that housed news personnel. Economic benefits to the regional economy from this marine wildlife encounter were substantial. Finally, on November 4, Humphrey swam under Golden Gate Bridge, ending a 25-day odyssey.

6.6 Tourism

According to estimates made by the San Francisco Convention and Visitors Bureau, about 2.65 million visitors, conventioneers, and business travellers who stayed in overnight accommodations visited the City of San Francisco in

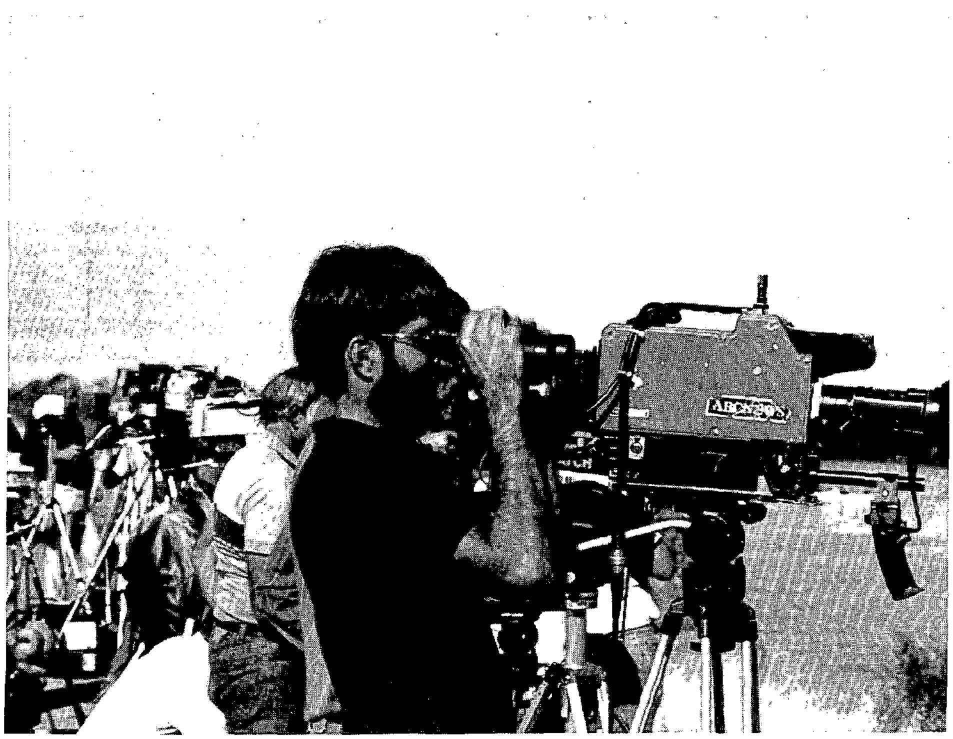


Figure 6.7(a-b) Humphrey swims under Shag Slough Bridge while his activities attract media coverage worldwide. Photos by Bog Gagnon.

1985. This was up about 3 percent over 1985. Falling gasoline prices, strong competition on airplane routes, and an active campaign waged by the city to attract tourists were among the things responsible for this growth.

A 1983 survey conducted by the Convention Bureau showed that most pleasure/ vacation trips to the city take place in the second and third quarters of the year (55 percent and 59 percent, respectively), while business trips remain constant throughout the year. The fourth quarter is the most popular time for conventions (18 percent of the visitors). Of the city's top seven tourist attractions, Fisherman's Wharf (1), Golden Gate Bridge (4), Pier 39 (6), and Golden Gate Park (7) have marine orientations.

Paid attendance at the Japanese Teahouse in Golden Gate Park, a popular tourist spot, shows the surge of summer tourism to the city (Figure 6.8). In both 1984 and 1985 attendance highs were reached in July and August. Total attendance in 1985 increased by about 2 percent over that in 1984 rising from 679,753 to 692,813.

An indication of the degree to which tourism contributes to the regional economy is given by the Convention Bureau. For those visitors staying in overnight accommodations in the city of San Francisco, it is estimated that they generated approximately $1.3 billion in expenditures. About 65 percent of these expenditures were for accommodations and restaurants and about 17 percent retail sales.

Another indication of the impact of travel and tourism on the regional economy are statistics on travel-related expenditures. In 1984, San Francisco ranked only behind Los Angeles as the California county with the greatest amount of travel expenditures and San Mateo, another Bay county, was close behind. For San Francisco, total expenditures were $3.5 billion and travel-generated employment was 76,276 jobs. Given the lower gas prices in 1985, figures for the year should be higher.

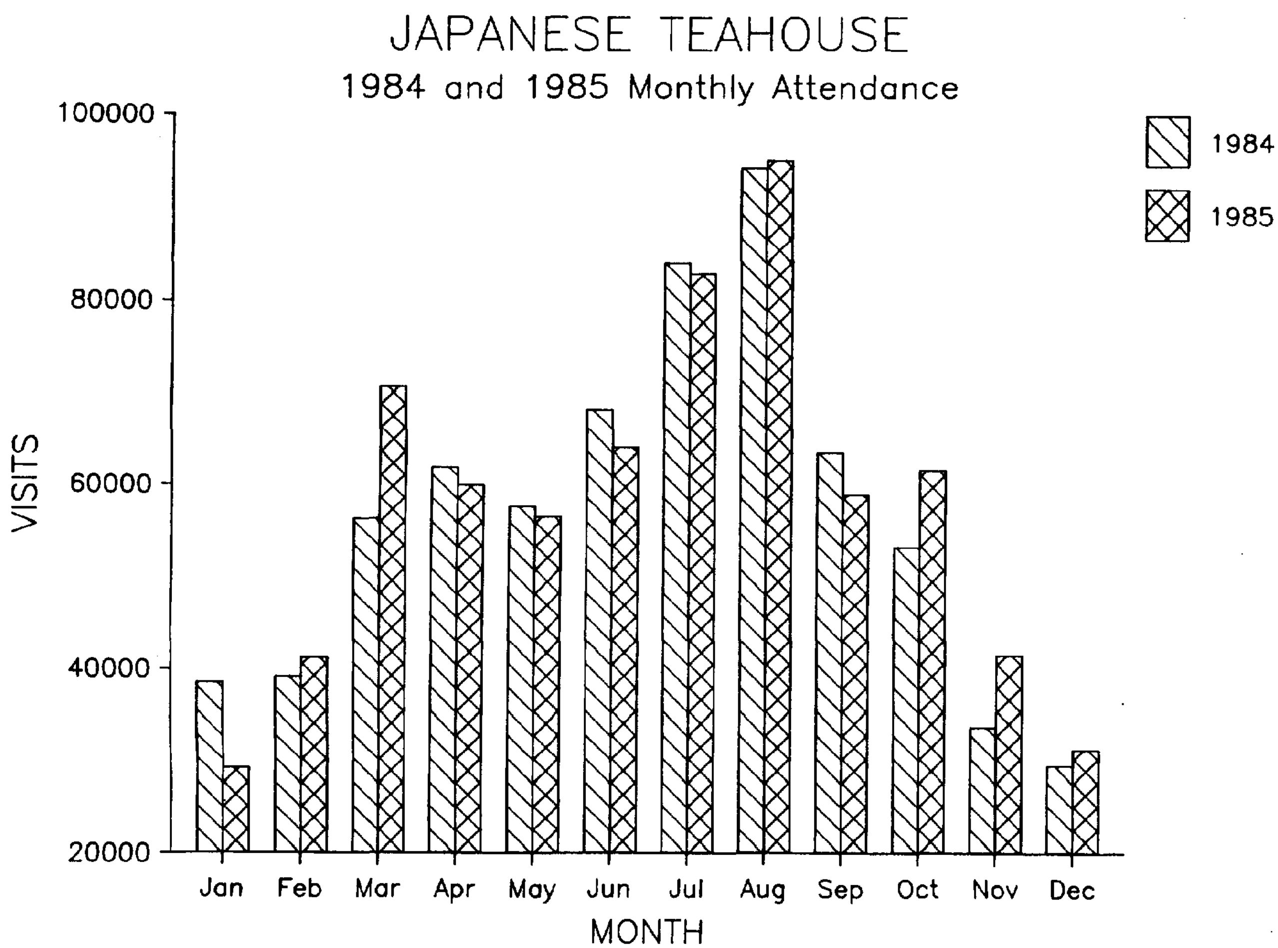


Figure 6.8 Number of paid visitors, Japanese Teahouse, Golden Gate Park, by month, 1984 and 1985.

7. TRANSPORTATION

Seven ports are in the San Francisco Bay area, and are referred to as the Golden Gate ports. These ports are located at the midpoint of the Pacific Coast, and are often thought of as being the mainline for cargo moving to and from the West Coast, the Midwest, the East Coast, and countries of the Pacific Rim. Some 5,000 ships move through the San Francisco Bay via the Golden Gate ports annually.

The Ports are located for easy approach to major transcontinental freeways, interstate highways, and railway routes such as Union and Southern Pacific for truck traffic and the movement of cargoes to and from different terminals (Figure 7.1). Their locality allows for a lesser amount of transit time between origin and destination within the US and overseas countries. Table 7.1 lists the terminals and Ports that handle the cargoes. San Francisco has the only and the largest passenger liner and cruise ships. Container cargo is handled at Oakland, Richmond, and San Francisco with service to the port of Sacramento and Stockton. The ports of Sacramento, Stockton, and San Francisco are equipped with elevators to ensure handling of large quantities of dry bulk and grain. Table 7.2 lists the primary facilities available during 1985 by ports.

Oakland is the largest of the Golden Gate Ports. Ninety-five percent of all container traffic is handled by that Port and is served by more than 40 container lines. Facilities are also available for breakbulk, heavy-lift, and other cargo. Approximately 85 percent of all the general cargo moving through the Bay is located or discharged at Oakland. Almost a third of all the west coast cotton exports go through the port.

A major topic of concern has been whether or not the US Ports are equipped to handle present and future trade. Greater water depths are required for larger vessels traveling within the United States ports, including San Francisco Bay (Figure 7.2). The quantity of cargo is greater in large vessels when compared to the smaller ones, the transport cost per ton of cargo is less as the vessel size increases. Larger vessels carry more cargo in a given time period, increasing the total revenue to the carrier. Channel maintenance and deepening projects are ongoing at many port areas around the U.S. including San Francisco Bay to provide access by all vessels travelling to the Bay (see section 7.2 Dredging).

7.1 Shipping

The Golden Gate ports have a traditional export orientation with major export cargo including agricultural products such as cotton, wheat, rice, animal feeds, fruits, vegetables, and vegetable oils, plus meat, hides, and tallow. Other major export products include petroleum products, electronic components, wood products, and containerized cargo. Imports have become more important to the ports due to the increased growth of the central California buying market, an annual volume of almost $200,000 million. Increased industry and high-technology such as the new General Motors-Toyota plant is expected to increase port activity in the Bay area.

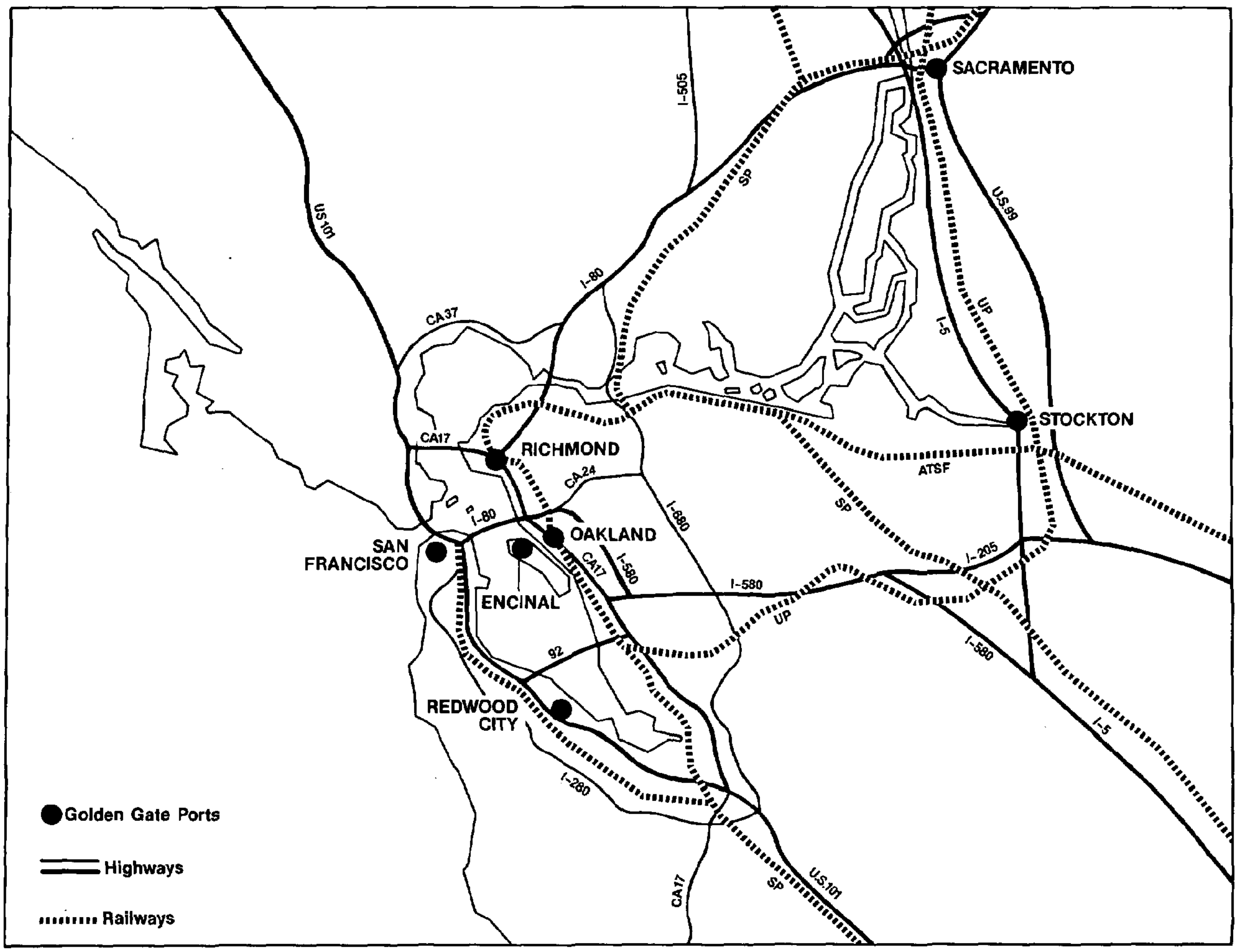


Figure 7.1 Locations of Golden Gate Ports and major land transportation routes.

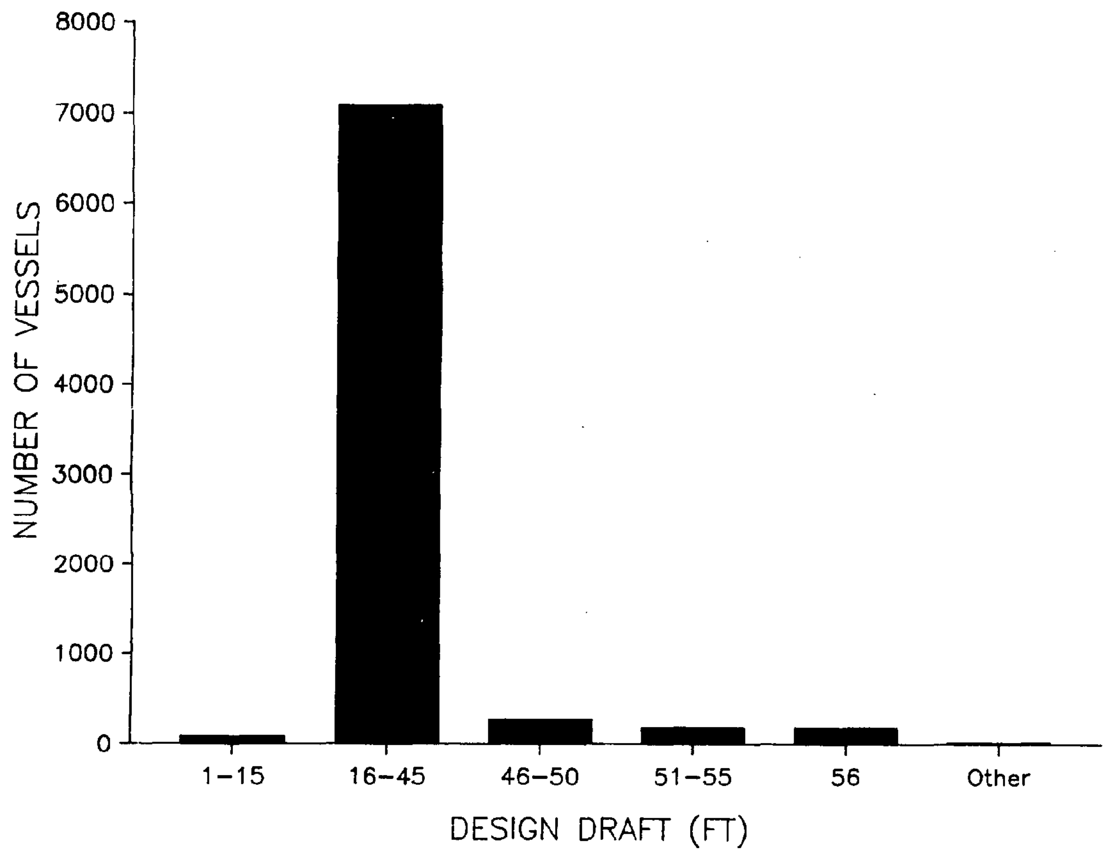


Figure 7.2 Number of vessels in foreign trade calling on ports of the United States by design draft, 1980.

Table 7.1 Cargo terminals and ports of the San Francisco Bay area, 1985.

Containers	Roll-on/Roll-off	Break-Bulk/General Cargo
*Oakland	Oakland	Encinal Terminals
*Richmond	Sacramento	Oakland
*San Francisco	San Francisco	Redwood City
	Stockton	Richmond
		Sacramento
		San Francisco
		Stockton
Neo-Bulk	**Dry Bulk & Grain**	**Liquid Bulk**
Oakland	Redwood City	Encinal Terminals
Redwood City	Richmond	Redwood City
Richmond	**Sacramento	Richmond
Sacramento	**Stockton	San Francisco
San Francisco	**San Francisco	Stockton
Stockton		Private petroleum facilities
Heavy Lifts	**Passenger Liners**	
All ports	***San Francisco	

* service to Sacramento and Stockton
** equipped with elevators
*** largest passenger liner and cruise ships

Source: Golden Gate Ports Association, Redwood City, California.

Table 7.2 Primary facilities available at ports of San Francisco Bay area, during 1985.

Port	Accommodation	Crane	Storage	Airport
Stockton	9 berths	2	transit-shed warehouse	Stockton
Sacramento	5 berths 2 barge slips	2	transit-shed warehouse	Sacramento San Francisco
Richmond	7 berths	4	warehouse	Oakland San Francisco
Oakland	29 berths	21	transit-shed refrigeration	Oakland
San Francisco	18 piers	6	transit-sheds refrigeration	San Francisco
Redwood	5 berths	0	warehouse	San Francisco
Encinal Terminal	6 berths	2	transit-shed	Oakland

Source: Port Authorities of Stockton, Sacramento, Richmond, Oakland, Redwood, San Francisco, and Encinal Terminal.

Stockton, an elevator equipped port for export of grain by vessels, also handles dry and liquid bulk and general cargoes. Terminals at Stockton have the capability for manufacturing, receiving, storing, and distributing a variety of products, such as feed supplements for livestock, liquid fertilizers, rice, gasoline and diesel fuel and other petroleum products. Total movement of materials through Stockton declined 10.5 percent in 1985 compared to 1984 (Table 7.3).

Richmond ranks 28th in tonnage among major US Ports with the capability of handling various types of cargo for export and import. One of the newest export cargo is cattle for the Japanese market. Tallow is another export commodity handled at the port for Japan, Taiwan, and Korea. A number of city-owned terminals are located at the port such as Levin-Richmond Corporation, the areas largest dry bulk terminal located on Richmond's Inner Harbor Channel. Total tonnage at Richmond was 18.0 million tons in 1985, a 13.7 percent increase over 1984.

California's capital port, Sacramento, during 1985 added three force flow bagging machines which increased their production of fertilizer by 50 percent. During September, for the first time California white fir logs were shipped to the People's Republic of China. This export is expected to continue and introduce a new market area for the port. Almonds now rank among the top five

Table 7.3 Total import and export tonnage, San Francisco ports, 1984 and 1985.

	Tonnage (short tons)		
Ports	1984	1985	1984-1985 % change
Richmond	15,853,883	18,031,790	+13.7
Redwood	559,663	416,665	-26.0
Sacramento	1,364,103	1,108,829	-18.7
San Francisco	1,897,000*	2,735,000*	+44.2
Stockton	3,047,410*	2,726,190*	-10.5
Oakland	13,750,799	13,155,992	-4.3
Encinal	145,900	270,500	+85.4

Source: Data from individual ports as listed.
* indicates data are in metric revenue tons.

exports to the Soviet Union. Eleven million pounds of almonds were shipped from the port in 1985, the largest single shipment of almonds ever from the port. Sacramento total tonnage decreased by 18.7 percent in 1985 from 1984.

The ratio of imports to exports at the port of San Francisco has remained unchanged in the last two years with a 50/50 split on total cargo and a 44 to 56 percentage ratio of import to export for containerized cargo in the last two years. Paper and newsprint, coffee and coffee extracts, hardware, meat and meat products lead the list of general cargo imports. Automatic data proessing machinery and automobiles are the top group in terms of dollar value. Leading export commodities based on tonnage include waste paper, synthetic resins, scrap metal, and cotton. In terms of dollar value, vechicle parts are at the top of the list, with construction machinery and synthetic organic pesticide replacing waste paper and scrap metal. During 1985 total tonnage at the port of San Francisco showed increases over 1984 (Table 7.3). The major gain was in container cargo, a 64 percent increase. Breakbulk cargo increased 16 percent and bulk cargo 15 percent (Figure 7.3). Port Authorities indicated the addition of two new shipping lines, the expanded service of two of the ports largest volume carriers, and the significant growth of cargo volume handled contributed to the increases.

Tables 7.4 and 7.5 list foreign import and export waterborne commerce at Golden Gate ports and the San Francisco Customs District during 1984 and 1985. The ports as a group showed a decline in foreign dollar value for both exports

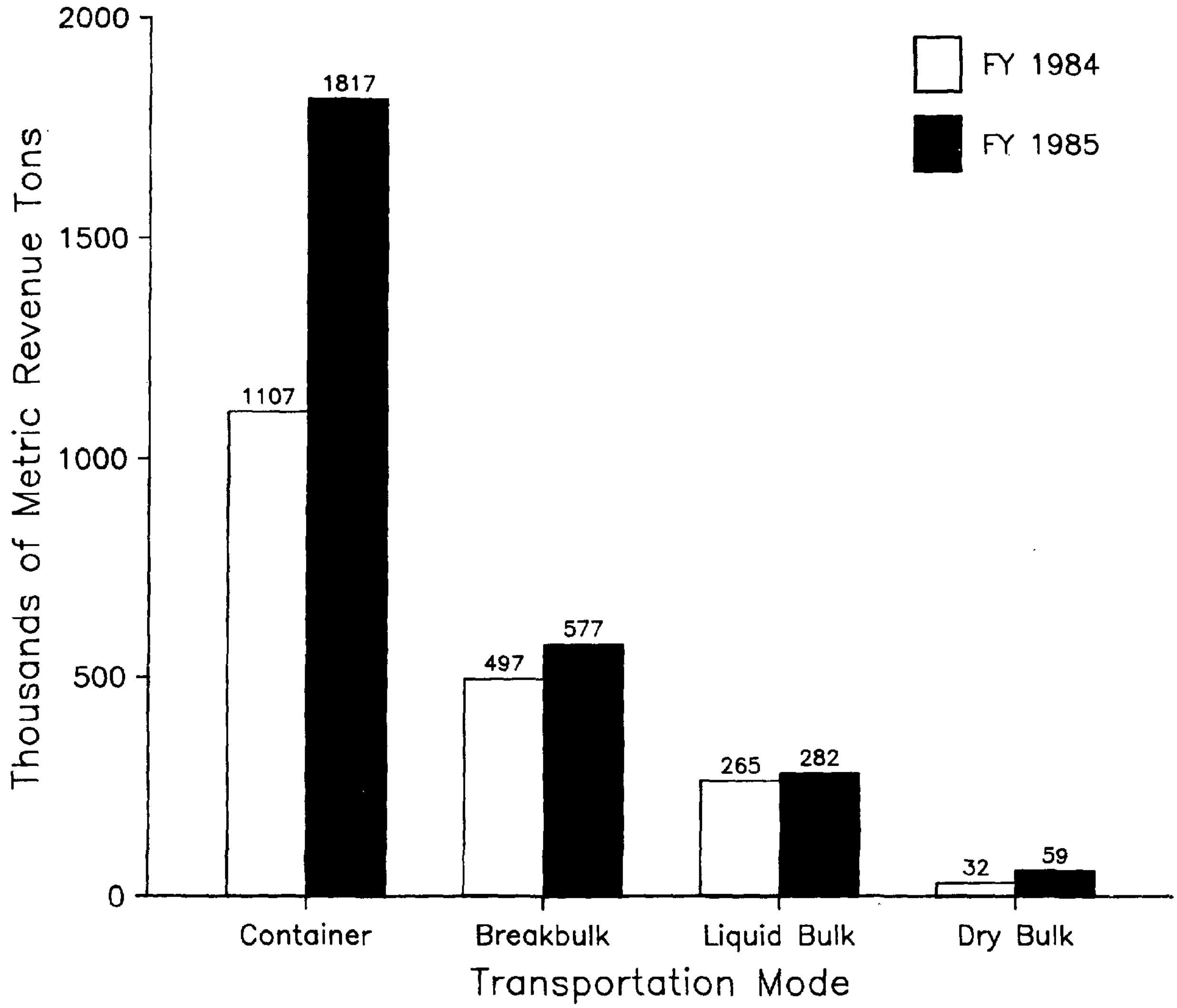


Figure 7.3 Port of San Francisco's market share by transportation mode, 1984 and 1985.

Table 7.4 Foreign import waterborne commerce, Golden Gate Ports, 1984-1985.

	Shipping Wt. (million of pounds)			Value (million of dollars)		
Ports	1984	1985	1984-1985 % change	1984	1985	1984-1985 % change
San Francisco	1,827	1,769	-3.2	1,436	1,655	+15.3
Stockton	697	609	-12.6	45	37	-17.8
Oakland	5,590	4,959	-11.3	7519	6,900	-8.2
Richmond	6,335	3,324	-47.5	1,139	704	-38.2
Alameda	797	439	-44.9	248	125	-49.6
Sacramento	328	288	-12.2	19	18	-5.3
Redwood	241	124	-48.6	13	15	+15.4
Totals:						
Golden Gate Ports	15,815	11,512	-27.2	10,419	9,454	-9.5
San Francisco Customs Dist.	18,676	15,174	-18.8	10,843	10,825	-0.2

Source: U.S. Department of Commerce, Bureau of Census; U.S. Waterborne Exports and General Imports.

Table 7.5 Foreign export waterborne commerce, Golden Gate Ports, 1984-1985.

	Shipping (millions of pounds)			Value (millions of dollars)		
Ports	1984	1985	1984-1985 % change	1984	1985	1984-1985 % change
San Francisco	1,170	853	-27.1	629	675	+7.3
Stockton	1,106	790	-31.4	110	100	-9.1
Oakland	5,547	6,050	+ 0.9	4,850	4,290	-11.6
Richmond	3,496	4,669	+30.9	424	489	+15.3
Alameda	158	23	-87.1	116	9	-92.2
Sacramento	1,943	1,846	-10.3	161	126	-21.7
Redwood	389	440	+13.1	5	16	+220.0
Totals:						
Golden Gate Ports	14,506	14,671	-1.1	6,295	5,705	+9.4
San Francisco Custom Dist.	22,357	22,705	+1.6	6,138	5,444	-11.3

Source: U.S. Department of Commerce, Bureau of the Census; U.S. Waterborne Exports and General Imports.

and imports. Shipping weight handled at the Golden Gate ports showed declines with increases only in exports at the ports of Oakland, Richmond, and Redwood City. The San Francisco Customs District showed the same declines as the Golden Gate ports.

Fog can delay cargo vessels to and from a destination for a short period of time. When heavy fog is present cargo vessels are halted until visibility is good and incoming vessels are given assistance when approaching the wharf. Strong waves and high winds can result in damages to ships and cargo. During the winter months the Port of Stockton and Sacramento experience considerable delays due mainly to fog and other weather factors. Winter months at San Francisco and in Northern California in 1985 were low in precipitation and storms. In the winter, cooler, drier air across the Sierra Nevada Range into the Central Valley of California and coastal regions, results in somewhat more cloudfree conditions and less fog than usual in the Bay area, but in the Sacramento Valley high pressure and fewer storms promotes more frequent and prolonged periods of fogginess. At both the ports of Sacramento and Stockton, increased frequency of heavy fog during January and December of 1985 delayed vessel transits through the shipping channels to these Ports. This was the only significant meteorologically related impact on vessel traffic in 1985. An increase in the number of storms would have tended to decrease such delays. In the past, deposits of silt in the channel from periods of heavy precipitation where flooding resulted caused some draft restrictions in the channels, requiring in some instances waits for high tide to facilitate passage.

7.2 Dredging

A summary of dredging operations within the San Francisco Bay area for fiscal year 1985 appears in Table 7.6. Eleven areas were dredged in 1985, ranging from 6 feet at the San Leandro marina to 55 feet in the San Francisco mainship channel. The quantity of material removed totalled 8,589,597 cubic yards for all projects done in 1985 at a cost of $17,146 million. Figure 7.4 shows the locations of the dredged areas. Dredging in the San Francisco Bay area shows little variation in the number of projects from year to year. Dredging is undertaken primarily to maintain water depths, as constant siltation from runoff of the Sierra foothills fills in navigable waterways. In addition to sediment removal, other areas are deepened to accomodate large vessels such as container ships at certain ports. Dredged material are disposed at two sites in the Bay area and one ocean site. Site disposal has recently become a concern in the dredging process, as existing sites have neared peak capacities.

The added six feet of deepening at the port of Stockton waterway will have will be enable 45,000 to 55,000 ton class ships up to 900 feet in length fully loaded to use the port. Partially loaded vessels up to the 80,000 ton class will be able to move through the channel. The port provided several million cubic yards of dredged materials for levee rehabilitation on a number of Delta islands. Dredged material was used to raise Venice Cut and Donlon islands to a marshland environment providing protected areas for fish, and a nesting area for wildlife. A total of over 500 acres of habitat was created and will be maintained.

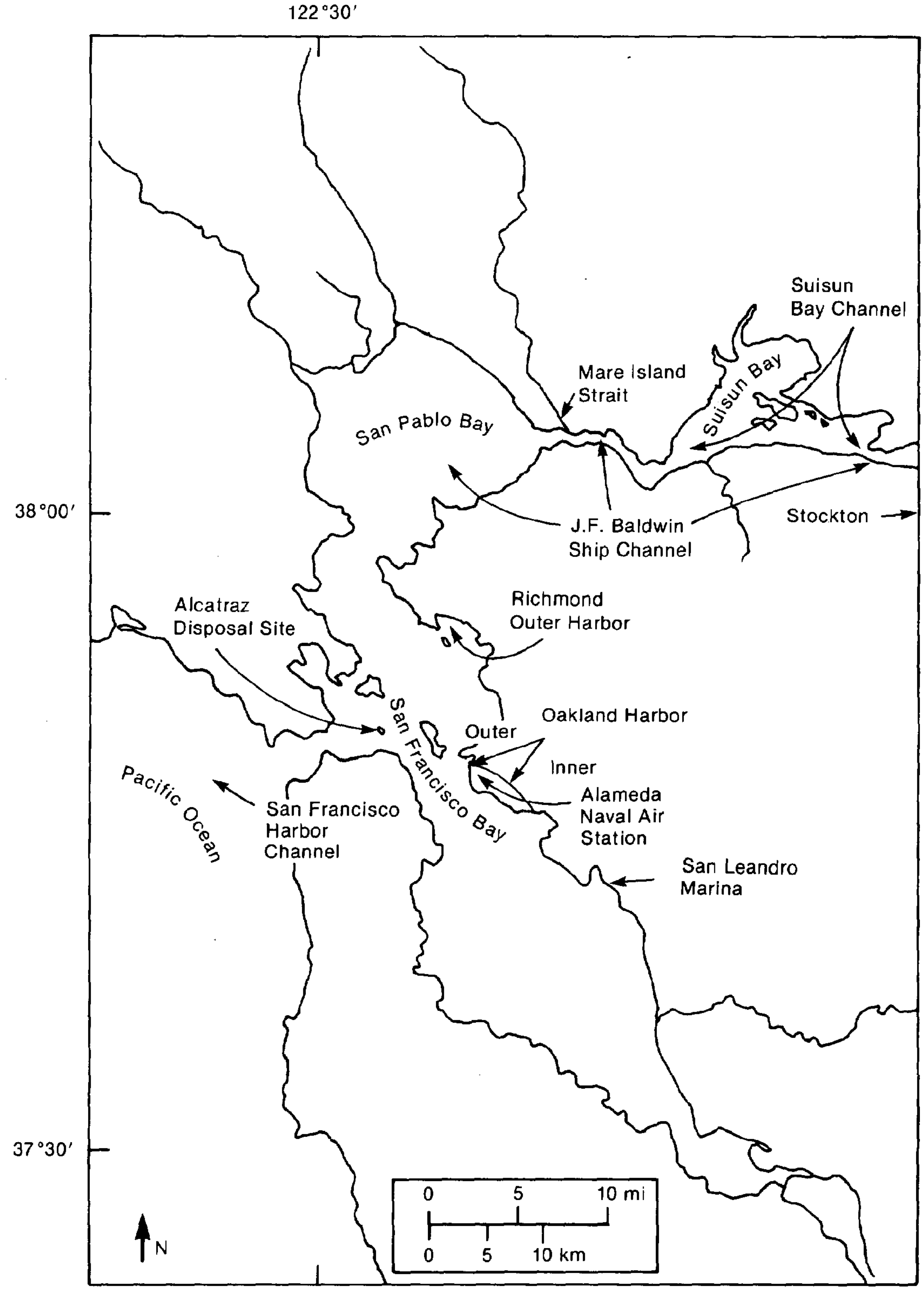


Figure 7.4 Map of San Francisco Bay area showing locations of dredge sites during 1985.

Over the past ten years, the port of Redwood City has spent millions of dollars to remodel and add new facilities to meet the present shipping needs and attract new businesses. The channel deepening project included dredging at side berths to 36 feet (mean lower low water). Channel conditions of this type enable vessels to enter the port safely and operate at these berths.

Table 7.6 Dredging Operations within San Francisco Bay area for Fiscal Year 1985, (October 1, 1984 to October 1, 1985).

Project Name	Depth (feet)	Start Date	End Date	Dollars (thousands)	Quantity Removed (cubic yards)
Mare Island Strait**	30' 36'	06Mar84 14Jun85	06Mar85 24Dec85	1,978 547	1,457,362 363,337
Suisun Bay Channel & Pinole Shoal**	36'	10Sep84	09Nov84	1,107	552,464
Richmond Outer Harbor**	35'	21Sep84	10Dec84	689	327,124
San Leandro Marina**	06'	06Aug84	30Sep85	1,052	254,271
J.F. Baldwin Ship Channel	45'	25Jan85	27Sep85	8,493	3,911,608
San Francisco Mainship Channel	55'	23Feb85	03Apr85	1,104	890,550
Oakland Outer Harbor	35'	23Jul85	13Aug85	485	196,300
Oakland Inner Harbor	35'	13Aug85 01Mar85	16Aug85 03Apr85	341	141,000
Suisun Bay Channel (Bulls Head Point)	30'	25Jul85	29Jul85	114	38,600
San Francisco Bay, Alcatraz Disposal Site	45'	21Jul85	20Aug85	469	96,981
Alameda Naval Air Station	42'	27Jul85	24Aug85	767	360,000
			Totals	17,146	8,589,597

** A portion of this project was dredged in FY84.

Source: U.S. Army Corps of Engineers.

8. POLLUTION

8.1 Summary of Pollution in San Francisco Bay

Pollution is a major national problem and concern. Some geographical areas are more fortunate than others with regards to levels of pollutants and the areas' natural abilities to assimilate these pollutants. San Francisco Bay is not one of the fortunate areas. The many potential sources of pollution, the reduced freshwater inflow, the constricted opening of the Bay to the open ocean, the difficulty in policing polluting sources, aging treatment facilities, obsolete pollutant level evaluation criteria, and intensified industrialization along the bay make it a prime candidate for deterioration as a result of pollution. The potential sources of pollution in San Francisco Bay are municipal and industrial wastewater discharges, urban runoff, Delta outflow, spill incidents, and aerial fallout. The major pollutants and their sources are listed in Table 8.1.

Table 8.1. Pollutant sources and pollutant types.

Pollutant source	Pollutant type
Municipal dischargers	Heavy metals,* oil and grease, organic chemicals,** organic material, other toxics
Industrial dischargers	Heavy metals,* oil and grease, organic chemicals, other toxics
Urban runoff	Suspended solids, heavy metals, petroleum hydrocarbons
Delta outflow	Pesticides, herbicides, suspended sediments, organic material, selenium, and other elements of subsurface agricultural waste drainage emanating from the western San Joaquin Valley (e.g. boron and molybdenum)
Spill incidents	Oil and hazardous substances (See Tables 8.2-8.4)
Aerial fallout	Bacteria, fungi, nitrous oxide, sulfur dioxide, solvents

* Includes arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, zinc, cyanide, thallium

** Includes phenols, solvents, PCBs

Programs have been established in the San Francisco area the past two years to monitor the wastewater discharges from both municipal and industrial dischargers. Although these programs are ambitious in their goals, there are problems both in determining the ambient water quality parameter levels in the Bay and in measuring the levels of pollutants entering the Bay. There is no historical data base available to make meaningful comparisons. The costs of sampling and analyzing data force sampling strategies to rely on sparse temporal and spatial sampling, which causes the data to be difficult to quantify. There is a problem in establishing allowable loadings of the Bay. For example, a high concentration of a pollutant from a small discharger might produce a detectable level of that pollutant in a sample, whereas a lower concentration of a pollutant from a larger discharger would be undetectable in its effluent. The resulting loading, though, from the larger discharger might have a more adverse effect on the environment. This loading might be permissable under current discharge permits. This precludes the setting of a single standard for wastewater discharges. The adminstrators for the municipal and industrial discharge monitoring programs have compelled the dischargers to monitor their discharges and ensure that they are in compliance with current requirements prior to the renewal renewal of the dischargers' permits.

The industrial monitoring program was designed to sample and analyze trace metals on a monthly basis and volatile organics on a bi-monthly schedule. The heavy metals sampling was expanded to a weekly scheme as copper, nickel, lead, selenium, zinc, and chromium were found in the wastewaters. Obtaining and analyzing a good sample for organics is difficult. Further work must be done in the area using bioassays to determine if the treatment plants are doing the job. A good indicator of the efficiency of organic removal by the plants is the amount of dissolved oxygen (DO) present in the receiving waters. The presence of this parameter indicates that materials requiring oxygen to decompose are either not present or are in insufficient quantities to cause alarm. With regards to this parameter, the health of the Bay has improved from the 1960s when DO levels in South Bay were almost nonexistent, and the levels in the northern Bay were low.

The municipal program, conducted from May 1984 to July 1985, was designed as a special priority pollutant monitoring program by 32 municipal wastewater treatment plants. The Regional Water Quality Control Board initiated this study to determine the types and concentrations of toxic pollutants discharged from municipal wastewater treatment plants and to determine whether these levels posed a threat to the environment.

The program was initiated to sample and analyze four major groups of toxic pollutants: volatile organic compounds, semi-volatile organic compounds, pesticides, and trace metals. Although it was found that most of the municipal waste water treatment plants discharge effluents containing a variety of toxic pollutants, the pretreatment and treatment processes of the plants under study removed a sufficient quantity of these toxics to place these plants at the lower end of a national scale. Overall, the toxic pollutant concentrations measured in the plants' effluents met the available criteria for acute (short-term) and chronic (long-term) toxicity for aquatic life.

Urban runoff is a major non-point source of untreated wastewater entering the Bay. This pollutant source carries oil and grease, suspended solids, and heavy metals to the Bay. Likewise, Delta outflow is a major contributor to the pollutant levels in the Bay. Since the agriculturalization of the Central Valley, the Sacramento and San Joaquin rivers have carried to the bay large quantities of pestcides, herbicides, organic material, and other elements of subsurface agricultural waste drainage emanating from the western San Joaquin Valley (e.g. boron and molybdenum). Aerial fallout is also a contributor of pollution to the area. However, the study and control of pollution from these non-point sources are difficult to assess and require Bay-wide coordination and cooperation among the various local municipalities.

Oil and chemical spills are also contributors to the pollution problem in San Francisco Bay. Although there has been considerable progress made world-wide in the control and clean-up of these events, acute toxic effects do result from them. Tables 8.2 to 8.4 list the spills of oil and hazardous substances for the San Francisco Bay Region as reported by the United States Coast Guard. The 12th Coast Guard District includes the coastal area from the California/Oregon border to the San Luis Obispo/Santa Barbara county line (Santa Maria River) and the San Joaquin - Sacramento River Delta.

It is not possible to extrapolate the state of pollution in the Bay from the data currently available. However, the findings of some studies indicate the extent of pollution in San Francisco Bay. The Bay Institute of San Francisco cited that "South Bay -- all of the Bay south of the Bay Bridge to San Jose -- for years has suffered from nutrient, circulation, and pollution problems, especially dissolved oxygen in its southern extremity." In the South Bay coliform bacteria counts have exceeded the standards set for water-contact recreation. High concentrations of the toxic heavy metals lead, zinc, copper, cadmium, mercury, and chromium have been found in the bottom sediments of the South Bay. The north and central regions of the Bay exhibit better water quality characteristics due to better flushing (U.S. Fish and Wildlife Service and the Bureau of Land Management).

Citizens for a Better Environment have stated that very high concentrations of heavy metals have been found in the sediments of South Bay. In addition, bioaccumulation of toxic pollutants has been observed in the tissues of striped bass and shellfish. The National Marine Fisheries Service has found a direct link between reproductive problems in striped bass, whose population has been declining for 10 years, and the presence of toxic pollutants.

Pollution by selenium is an issue that has caused much concern recently. High levels of the element were discovered in Kesterson Reservoir. Shortly thereafter, mortalities and deformities were observed in fish, plants, and waterfowl. The first phase of a U.S. Fish and Wildlife Service study on the effects of selenium in waterfowl found that selenium in the diet caused embryo mortality and deformities; lower duckling survival and weights were also observed. After the discoveries in Kesterson, monitoring for this substance was begun in some of the tributary waters. The Interagency Delta Health Aspects Monitoring Program reported, however, that no elevated concentrations of this substance were found in the San Joaquin River, the water most likely to show contamination by the same source that affected Kesterson Reservoir. The Bay Institute, though, reports high concentrations of selenium from analyses of fish livers and the sampling of shellfish and waterfowl in South Bay. Whether these levels are the result of agricultural wastewater or the discharges of the refineries and other industries located along the South Bay has not been resolved. This highlights the need for more data sampling and better water quality monitoring.

To clean the waters of the Bay and keep them clean, several recommendations have been made by various agencies and organizations in the Bay area. These are the following:

1) total compliance with existing standards must be attained,
2) more stringent criteria for the evaluation of water quality should be established as some of the existing standards are out-of-date,
3) uniform discharge standards should be set,
4) a better and stricter monitoring program should be established,
5) a treatment scheme should be devised and implemented for urban runoff, which has remained unchecked as a major source of pollutants to the Bay, and
6) careful evaluation must be made before additional freshwater flow is diverted from the Sacramento-San Joaquin River system.

These are some, but not all, of the issues that must be addressed in the continuing effort to improve the quality of the San Francisco Bay estuarine system.

Table 8.2.--Spills of 1000 gallons or greater, 12th Coast Guard District, 1985.

Material	Gallons Entering Water	Date	Location	Source
#2 Diesel	60,000*	March 3	38 46'N, 124 45'W** 50 mi. W of Pt. Arena	Tug Willamet Pilot III (SANK)
#2 Diesel	1,800*	April 8	41 28'N, 124 05'W** S. of Klamath River	F/V Missionary (AGROUND)
Gasoline	40,000*	April 12	Treasure Island	Storage tank (inventory shortage)
#2 Diesel	1,900	April 23	Clipper Yacht Harbor Marina, Sausalito	
Deasphalted Oil	200	July 26	Pt. Orient, Richmond	Chevron, USA
Aviation Fuel (jet)	60	August 21	Sierra Pt. and Lagoon Way, Brisbane	Southern Pacific Pipeline
#2 Diesel	3,000	September 14	Monterey Bay**	F/V Bechy
JP-5	1,500	September 18	Oakland	USS Enterprise
Lube Oil	2,200	December 6	Pier 80, San Francisco	M/V Margrett Lykes
#2 Diesel	5,050	December 28	Oakland	USS Kansas City

Data from the USCG Marine Safety Office, San Francisco Bay.

* Potential amount spilled although no pollution sightings were made.

** Spill occured outside San Francisco Bay.

Table 8.3.--A sample of hazardous substances spills, 12th Coast Guard District, 1985.

Material	Amount*	Date	Location	Source
Cyanide, 1%	155 lbs**	January 3	Shipper, Oakland	Shipping Container
2,4,5-Trichloro-phenoxy Acetic Acid	55 gals	January 17	South San Francisco	Ruptured Drum
Sulfur (molten)	6,000 gals	January 19	Benicia Bridge	Truck Accident
Benzene***	168 gals	January 30	Pt. Orient, Richmond	Pipe Rupture
Ammonia (gas)	Unknown	March 27	Anchorage 7, San Francisco Bay	Leaky Valve, T/V GAS GLORIA
Black Liquor	30,000 gals	April 18	Eureka****	Louisiana Pacific
Dinitrotoluene	10 gals	June 3	SPRR Yard, Oakland	Leaky Tank Car
Asbestos/Methyl Ethyl Ketone	1 ton/ 265 gals	August 21	Berkeley	Criminal Dumping
PCB	3,000 gals	August 28	Port of Richmond	Leaky Transformers
Solvent (UN1225)	55 gals	September 11	Schnitzer Steel, Oakland	Leaky Drum
Hydrogen Peroxide	60 gals	October 17	Maersk Lines,Oakland	Leaky Drums
Sodium Hydro-sulfide	Unknown	October 23	Pak Tank, Richmond	Berm Draining
Monobutyltintri-chloride	110 gals	October 29	Schnitzer Steel, Oakland	Drum Shredding
Hydrochloric Acid	19 gals	November 22	Hayward	Ruptured Container

Data from the USCG Marine Safety Office, San Francisco Bay.

* The majority of incidents involving hazardous substances occur on land within Coast Guard jurisdiction. An unquantifiable amount of the substances may have found its way to Bay waters, but in a quantity far below what is listed in Table 8.3 as the amount spilled.

** The weight of the package was 155 lbs and contained cyanide at 1%.

*** Actually spilled into Bay waters.

**** Spilled into Pacific Ocean.

Table 8.4.--Spills in the 12th Coast Guard District, by month, 1985.

Month	Oil*	Hazardous Materials	Other**	Totals
January	33	7	6	46
February	34	2	6	42
March	52	3	3	58
April	26	8	6	40
May	39	9	7	55
June	43	10	5	58
July	35	3	5	43
August	45	4	11	60
September	43	4	3	50
October	40	8	9	57
November	40	4	3	47
December	34	1	3	38
TOTALS	464	63	67	594

Data from the USCG Marine Safety Office, San Francisco Bay.

* These numbers represent all oil spills and include unidentified substances that created a sheen, film, sludge or emulsion.

** These numbers represent those spills involving natural substances such as algae, jellyfish and pollen.

9. RESEARCH ACTIVITIES

This section consists of a summary of research activities conducted by universities, government, and industry in the San Francisco Bay area during 1985. This information is the result of a questionaire which was distributed by the Tiburon Center for Environmental Studies to 300 San Francisco Bay and Estuarine Association members for the assessment. The survey results include the following:

1. Title of study
2. Project director (name, address, phone)
3. Geographical area of study
4. Period of time study conducted
5. Funding agency
6. Repository of data
7. When data will be available

1. TITLE OF STUDY: Bioavailability of trace elements

PROJECT DIRECTOR: Samuel N. Luoma
Mail Stop 465
Water Resources Division
345 Middlefield Road
Menlo Park, California 94025
Telephone (415) 323-8111 extension 2834

AREA OF STUDY: San Francisco Bay

ENVIRONMENTAL WINDOW: 1975-present

FUNDING AGENCY: U.S. Geological Survey

REPOSITORY OF DATA: U.S. Geological Survey (same address as above)

DATA AVAILABILITY DATE: Published periodically in reference journals

* * * * * *

2. TITLE OF STUDY: Diked Baylands Wildlife Study

PROJECT DIRECTOR: James J. Mc Kevitt, Field Supervisor
U.S. Fish and Wildlife Service
Division of Ecological Services
2800 Cottage Way, Rm. E-1803
Sacramento, California 95825
Attn: Ruth T. Pratt, Fish and Wildlife Biologist
Telephone (916) 978-4613

AREA OF STUDY: San Francisco Bay

ENVIRONMENTAL WINDOW: October 1982 through September 1989

FUNDING AGENCY: U.S. Fish and Wildlife Service

REPOSITORY OF DATA: U.S. Fish and Wildlife Service (same address as above)

DATA AVAILABILITY DATE: Interim report scheduled for completion September 30, 1986. Final report will be completed by June 1990.

* * * * * *

3. TITLE OF STUDY: John F. Baldwin Ship Channel Phase III Hydraulic Model Tests (effect on Delta salinity intrusion resulting from deepening navigation channels)

PROJECT DIRECTOR: Thomas Wakeman, Model Director
The Bay Model
2100 Bridgeway Blvd.
Sausalito, California 949-1753
Telephone (415) 332-5485

AREA OF STUDY: San Francisco (main bay), San Pablo, and Suisun Bays

ENVIRONMENTAL WINDOW: August - December 1985

FUNDING AGENCY: U.S. Army Corps of Engineers, San Francisco District

REPOSITORY OF DATA: U.S. Army Corps of Engineers, San Francisco District

DATA AVAILABILITY DATE: Mid-summer 1986

4. TITLE OF STUDY: Further Studies Evaluating the Freshwater Asiatic Clam, Corbicula fluminea, for Monitoring the Sublethal Impact of Point Source Discharges

PROJECT DIRECTOR: Christopher Foe
Department of Land, Air and Water Resources
University of California
Davis, California 95616
Telephone (916) 752-0692

AREA OF STUDY: San Francisco Bay

ENVIRONMENTAL WINDOW: 1983-84

FUNDING AGENCY: State Water Resources Control Board

REPOSITORY OF DATA: University of California, Davis

DATA AVAILABILITY DATE: June, 1985

* * * * * *

5. TITLE OF STUDY: Toxic Chemicals in San Francisco Bay Sediments and Fish: Relationships with Mixed-Function Oxidase Activity and Histopathological Abnormalities in Starry Flounder (Slatichthys stellatus)

PROJECT DIRECTOR: Robert B. Spies
Lawrence Livermore National Laboratory
University of California
Environmental Science Division
Livermore, California 94550
Telephone (415) 422-5792

AREA OF STUDY: San Francisco Bay

ENVIRONMENTAL WINDOW: 1984-85

FUNDING AGENCY: State Water Resources Control Board

REPOSITORY OF DATA: Lawrence Livermore National Laboratory

DATA AVAILABILITY DATE: July, 1985

* * * * * *

6. TITLE OF STUDY: Publicly-owned Treatment Works Discharges of Priority Pollutants

PROJECT DIRECTOR: Theresa G. Rumjahn
California Regional Water Quality Control Board
1111 Jackson Street
Oakland, California 94607
Telephone (415) 464-0455

AREA OF STUDY: San Francisco Bay

ENVIRONMENTAL WINDOW: June 1984 to July 1986

FUNDING AGENCY: Local government, POTWs data compiled by the Regional Water Quality Control Board

REPOSITORY OF DATA: Regional Water Quality Control Board

DATA AVAILABILITY DATE: June, 1986

7.	TITLE OF STUDY:	Effect of Agricultural Drainiage Water on Micro Algae in San Francisco Bay
	PROJECT DIRECTOR:	Michael Josselyn Tiburon Center for Environmental Studies San Francisco State University P.O. Box 855 Tiburon, California 94920 Telephone (415) 435-1717
	AREA OF STUDY:	San Pablo and Suisun Bays
	ENVIRONMENTAL WINDOW:	1984-85
	FUNDING AGENCY:	U.S. Bureau of Reclamation
	REPOSITORY OF DATA:	U.S. Bureau of Reclamation
	DATA AVAILABILITY DATE:	Published as technical report by U.S.B.R.

* * * * * *

8.	TITLE OF STUDY:	Evaluation of Wetland Habitat Change in San Francisco Bay 1954-1985
	PROJECT DIRECTOR:	Michael Josselyn Tiburon Center for Environmental Studies San Francisco State University P.O. Box 855 Tiburon, California 94920 Telephone (415) 435-1717
	AREA OF STUDY:	Suisun, San Pablo and San Francisco Bays
	ENVIRONMENTAL WINDOW:	1985-1987
	FUNDING AGENCY:	U.S. Fish and Wildlife Service
	REPOSITORY OF DATA:	U.S. Fish and Wildlife Service
	DATA AVAILABILITY DATE:	Technical report to USFWS in 1987

* * * * * *

9.	TITLE OF STUDY:	Feasibility of Landfill Removal to Create Wetland Habitat
	PROJECT DIRECTOR:	Michael Josselyn Tiburon Center for Environmental Studies San Francisco State University P.O. Box 855 Tiburon, California 94920 Telephone (415) 435-1717
	AREA OF STUDY:	Benecia
	ENVIRONMENTAL WINDOW:	Unknown
	FUNDING AGENCY:	California Department of Parks and Recreation
	REPOSITORY OF DATA:	San Francisco State University
	DATA AVAILABILITY DATE:	Report to be completed in 1986

10. TITLE OF STUDY: Interagency Ecological Studies Program for the San Francisco Bay-Delta estuary

PROJECT DIRECTOR: (Agency Coordinators)

Pete Chadwick (Chairman)
California Department of Fish and Game
4001 North Wilson Way
Stockton, California 95205
Telephone (209) 466-4421

Marty Kjelson
U.S. Fish and Wildlife Service
4001 North Wilson Way
Stockton, California 95205
Telephone (209) 466-4421

Jim Arthur
U.S. Bureau of Reclamation
2800 Cottage Way
Sacramento, California 95825
Telephone (916) 445-1820

Dick Kretsinger
California Department of Water Resources
P.O. Box 100
Sacramento, California 95801
Telephone (916) 445-1820

Pete Antilla
U.S. Geological Survey
2800 Cottage Way
Sacramento, California 95825
Telephone (916) 978-4648

Dave Berringer
California Water Resources Control Board
P.O. Box 2000
Sacramento, California 95810
Telephone (916) 352-9870

AREA OF STUDY: San Francisco Bay-Delta estuary

ENVIRONMENTAL WINDOW: (By program)

Suisan Marsh 1970 - present
Fish Facilities 1970 - present
Fisheries/Water Quality 1970 - present
Delta Outflow
  Biological 1980 - present
  Hydrodynamic 1985 - present
Data Management 1985 - present

FUNDING AGENCY:

U.S. Bureau of Reclamation
U.S. Fish and Wildlife Service
U.S. Geological Survey
California Department of Water Resources
California Department of Fish and Game
California Department of Water Resources Control Board

REPOSITORY OF DATA: Environmental Protection Agency STORET system

DATA AVAILABILITY DATE: Available upon request

11. TITLE OF STUDY: Ecology of Suisun Marsh Fishes

PROJECT DIRECTOR: Peter B. Moyle
Wildlife and Fisheries Biology
University of California, Davis
Davis, California 95616

AREA OF STUDY: Suisun Marsh

ENVIRONMENTAL WINDOW: January 1979 to present

FUNDING AGENCY: State Department of Natural Resources

REPOSITORY OF DATA: DWR (Central District), UCD (Peter Moyle)

DATA AVAILABILITY DATE: 1979-1983 summarized in P. Moyle et al. (1985), Fishery Bulletin 84(1):105-117. Other data in Annual Reports

* * * * * *

12. TITLE OF STUDY: Status and Trends Program (West Coast) - Sediment Quality Triad

PROJECT DIRECTOR: Ed Long
NOAA/National Ocean Service
CEAB/Pacific Office
7600 Sand Point Way, NE BIN 15700
Seattle, Washington 98115
Telephone (206) 526-6338

AREA OF STUDY: San Francisco Bay

ENVIRONMENTAL WINDOW: Summer 1985

FUNDING AGENCY: National Oceanic and Atmospheric Administration

REPOSITORY OF DATA: NOAA (Seattle address above)

DATA AVAILABILITY DATE: 1986

* * * * * *

13. TITLE OF STUDY: Reproductive success and organic contaminant exposure in Platichthys stellatus from San Francisco Bay

PROJECT DIRECTOR: Robert B. Spies
Lawrence Livermore National Laboratory
University of California
Environmental Sciences Division
Livermore, California 94550
Telephone (415) 422-5792

AREA OF STUDY: San Pablo Bay, off Berkeley/Richmond, off Alameda, off Candlestick/Hunter's Points and suspected hotspots

ENVIRONMENTAL WINDOW: 1982 - 1987

FUNDING AGENCY: NOAA

REPOSITORY OF DATA: NOAA/NOS (Seattle) and LLNL

DATA AVAILABILITY DATE: Some data presently available

14\. TITLE OF STUDY: A field trial of the sediment quality triad

PROJECT DIRECTOR: Peter Chapman
E.V.S. Consultants
(contact Ed Long 206-526-6338, NOAA Seattle)

AREA OF STUDY: San Pablo Bay off Alameda and Islais Creed Waterway

ENVIRONMENTAL WINDOW: July 1985

FUNDING AGENCY: NOAA/NOS (Seattle)

REPOSITORY OF DATA: NOAA/NOS (Seattle)

DATA AVAILABILITY DATE: February 1986

* * * * * *

15\. TITLE OF STUDY: Benthic Surveillance Project of the National Status and Trends Program

PROJECT DIRECTOR: Donald Malins
National Marine Fisheries Service
(contact Ed Long 206-526-6338, NOAA/Seattle)

AREA OF STUDY: off Hunter's Point, off Alameda, off Richmond, and off Vallejo

ENVIRONMENTAL WINDOW: summers 1984 and 1985

FUNDING AGENCY: NOAA/NOS (Seattle)

REPOSITORY OF DATA: NOAA/NOS (Seattle)

DATA AVAILABILITY DATE: February 1986

* * * * * *

16\. TITLE OF STUDY: Bivalve Surveillance Project of the National Status and Trends Program

PROJECT DIRECTOR: Unknown
(contact Ed Long 206-526-6338, NOAA/Seattle)

AREA OF STUDY: off Semple Point, off Point San Pedro, off eastern Yerba Buena Island, off Candlestick Point

ENVIRONMENTAL WINDOW: fall 1985

FUNDING AGENCY: NOAA/NOS (Seattle)

REPOSITORY OF DATA: NOAA/NOS (Seattle)

DATA AVAILABILITY DATE: early 1987

17. TITLE OF STUDY: Historical Data Review of the National Status and Trends Program

PROJECT DIRECTOR: Alan Mearns
NOAA/Seattle

AREA OF STUDY: San Francisco Bay

ENVIRONMENTAL WINDOW: Unknown

FUNDING AGENCY: NOAA/NOS (Seattle)

REPOSITORY OF DATA: NOAA/NOS (Seattle)

DATA AVAILABILITY DATE: West Coast body burden report (DDT and PCBs in shellfish and fish), due January 1986; nationwide data catalog, due November 1985; and nationwide body burden report, due July 1986

* * * * * *

18. TITLE OF STUDY: Water Environment Studies Program

PROJECT DIRECTOR: Richard Thall
James W. Dent Education Center
1936 Carlotta Drive
Concord, California 94519-9989
Telephone (415) 682-8000

AREA OF STUDY: Suisun-Honker Bay region

ENVIRONMENTAL WINDOW: March - June, and September - December 1985

FUNDING AGENCY: Mt. Diablo Unified School District

REPOSITORY OF DATA: James W. Dent Education Center

DATA AVAILABILITY DATE: late 1986

* * * * * *

19. TITLE OF STUDY: Muzzi Marsh Monitoring, Costa Madera, California

PROJECT DIRECTOR: Phyllis M. Faber
212 Del Casa
Mill Valley, California 94941
Telephone (415) 388-6002

AREA OF STUDY: Muzzi Marsh in Costa Madera

ENVIRONMENTAL WINDOW: 1979-1986

FUNDING AGENCY: Golden Gate Bridge, Highway, Transportation District

REPOSITORY OF DATA: Same as above

DATA AVAILABILITY DATE: Fall 1986

20. TITLE OF STUDY: Tidal and Tidally-Averaged Circulation Characteristics of Suisan Bay, California

PROJECT DIRECTOR: L.H. Smith and R.T. Cheng
U.S. Geological Survey
Water Resources Division
345 Middlefield Road MS-496
Menlo Park, California 94025

AREA OF STUDY: Suisun Bay

ENVIRONMENTAL WINDOW: 1984-1985

FUNDING AGENCY: U.S. Geological Survey

REPOSITORY OF DATA: Four-Agency Group

DATA AVAILABILITY DATE: Available now

* * * * * *

21. TITLE OF STUDY: Pacific Herring Research Project

PROJECT DIRECTOR: Paul Reilly
California Department of Fish and Game
411 Burgess Dr.
Menlo Park, California 94025
Telephone (415) 326-0324

AREA OF STUDY: San Francisco Bay

ENVIRONMENTAL WINDOW: Ongoing October to March since 1982

FUNDING AGENCY: Tax on commercial herring landings mandated by legislature and administrated by California Department of Fish and Game

REPOSITORY OF DATA: California Department of Fish and Game, Menlo Park

DATA AVAILABILITY DATE: Now available in administrative reports

* * * * * *

22. TITLE OF STUDY: Carbon to Chlorophyll Ratios in the Sacramento - San Joaquin Delta

PROJECT DIRECTOR: Karen Taberski
Department of Water Resources
Central District
3251 "S" Street
Sacramento, California 95818
(916) 445-9541

AREA OF STUDY: Sacramento-San Joaquin Delta, east of Ryer Island

ENVIRONMENTAL WINDOW: March through May 1985

FUNDING AGENCY: Department of Water Resources, State of California

REPOSITORY OF DATA: Technical report of the Department of Water Resources

DATA AVAILABILITY DATE: Available now from Project Director. Technical report to be published December 1986

23. TITLE OF STUDY: Phytoplankton Growth Rates in the Sacramento-San Joaquin Delta

PROJECT DIRECTOR: Karen Taberski
Department of Water Resources
3251 "S" Street
Sacramento, California 95818
Telephone (916) 445-9541

AREA OF STUDY: Sacramento - San Joaquin Delta, east of Suisun Bay

ENVIRONMENTAL WINDOW: April through November 1985

FUNDING AGENCY: Department of Water Resources, State of California

REPOSITORY OF DATA: Technical report of the Department of Water Resources

DATA AVAILABILITY DATE: Available now from Project Director. Technical report to be published December 1986

* * * * * *

24. TITLE OF STUDY: Bay Watch (Survey of about 60 public and private organizations involved with San Francisco Bay)

PROJECT DIRECTOR: Joan Patton
Conservation Director
San Francisco Bay Chapter
The Oceanic Society
Bldg. E, Fort Mason
San Francisco, California 94123
Telephone (415) 441-5970

AREA OF STUDY: San Francisco Bay region

ENVIRONMENTAL WINDOW: 1985-86

FUNDING AGENCY: Supported partially by Oceanic Society

REPOSITORY OF DATA: Conference report and separate bibliography for the "State of the Bay" conference in the spring of 1987

DATA AVAILABILITY DATE: Spring of 1987

* * * * * *

25. TITLE OF STUDY: Interagency Ecological Study Program for the Sacramento - San Joaquin Estuary Juvenile Salmon Study

PROJECT DIRECTOR: Martin A. Kjelson

AREA OF STUDY: Delta, Estuary, and Bay

ENVIRONMENTAL WINDOW: 1978 to present

FUNDING AGENCY: U.S. Fish and Wildlife Service
California Department of Fish and Game
Department of Water Resources
U.S. Bureau of Reclamation

REPOSITORY OF DATA: EPA STORET database

DATA AVAILABILITY DATE: August 1, 1986

26. TITLE OF STUDY: Parameters controlling benthic macro-algae distribution in San Francisco Bay. (M.A. Thesis Research)

PROJECT DIRECTOR: Naomi Phillips
Sonoma State University
Rohnert Park, California 94928
Telephone (707) 664-2189

AREA OF STUDY: North reach of San Francisco Bay from mouth to Carquinez Bridge - Intertidal algal communities

ENVIRONMENTAL WINDOW: 1982 to present (study is continuing)

FUNDING AGENCY: None

REPOSITORY OF DATA: Sonoma State University

DATA AVAILABILITY DATE: August 1987

* * * * * *

27. TITLE OF STUDY: Performance Standards and Guidelines for Salt Marsh Restoration based on a Study of Nine Undisturbed Marshes in San Francisco Bay (Ph. D. dissertation)

PROJECT DIRECTOR: Katherine Cuneo
7 Poco Paso
San Rafael, California 94903
Telephone (415) 479-2814

AREA OF STUDY: San Francisco Bay and estuary. From north to south the marshes are: Mare Island, China Camp, San Pablo, Corte Madera, Hoffman, Bird Island, San Leandro Bay, Dumbarton, and Palo Alto

ENVIRONMENTAL WINDOW: 1985

FUNDING AGENCY: Landscape Architecture Department (University of California, Berkeley)

REPOSITORY OF DATA: University of California, Berkeley

DATA AVAILABILITY DATE: Spring 1987

ACKNOWLEDGMENTS

We wish to thank Pollie A. Jackson for her assistance in preparation of this report and the persons within and outside NOAA who participated in the review process. We also appreciate the editorial efforts of John O. Ellis and the advice and assistance of Robert E. Dennis in the planning and development of this prototype assessment.

Many organizations and individuals contributed information and guidance toward the preparation of this assessment. The cooperation offered by the following is particularly noteworthy:

Association of Bay Area Governments
Bay Area Dischargers Association
Bay Conservation and Development Commission
Bay Institute of San Francisco
California Department of Boating and Waterways
California Department of Commerce
California Department of Fish and Game
  Long Beach Office
  Sacramento Office
  Stockton Office
California Department of Motor Vehicles
California Department of Recreation and Parks
California Department of Water Resources
  Central District
  Division of Operations and Maintenance
California Regional Water Control Board
  San Francisco Bay Region
California Sea Grant
Chevron Standard Oil
Citizens for a Better Environment
East Bay Regional Park District
Encinal Terminal
Environmental Protection Agency
  Water Division (San Francisco)
  STORET (Washington, D.C.)
Fisherman's Wharf Association
Golden Gate Fisherman's Association
Golden Gate National Recreation Area
Meatball Bait Company
National AUDUBON Society
National Park Service
NOAA, National Marine Fisheries Service
  Monterey Office
  National Fishery Statistics Program
  Terminal Island Office
  Tiburon Laboratory
NOAA, National Ocean Service
  Tidal Datums Branch
NOAA, National Climatic Data Center
NOAA, National Weather Service
Oceanic Society
Point Reyes National Seashore

ACKNOWLEDGMENTS (Continued)

Port of Oakland
Port of Richmond
Port of Sacramento
Port of Stockton
San Francisco City and County
  Department of Recreation and Parks
San Francisco Chamber of Commerce
San Francisco Water Quality Board
San Francisco Visitors and Convention Bureau
San Francisco Bay National Wildlife Refuge
San Francisco Bay and Estuarine Association
San Francisco Boardsailing Association
Security Pacific Bank
United Anglers of California
Tiburon Center for Environmental Studies
U.S. Army Corps of Engineers
U.S. Coast Guard District 12
U.S. Fish and Wildlife Service
U.S. Geological Survey
  Water Resources Division, Menlo Park
Yale School of Forestry and Environmental Studies

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
ASSESSMENT AND INFORMATION SERVICES CENTER, E/AI1
Washington, DC 20235

OFFICIAL BUSINESS
Penalty for Private Use, $300

AN EQUAL OPPORTUNITY EMPLOYER

POSTAGE AND FEES PAID
U S DEPARTMENT OF COMMERCE
COM-210

FIRST CLASS

U.S.MAIL